Province of British Columbia
Ministry of Environment

GUIDELINES FOR MINIMUM STANDARDS IN WATER WELL CONSTRUCTION PROVINCE OF BRITISH COLUMBIA

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GUIDELINES FOR MINIMUM STANDARDS IN WATER WELL CONSTRUCTION — PROVINCE OF BRITISH COLUMBIA

PART 1

1. INTRODUCTION & ACKNOWLEDGEMENTS

In preparing these guidelines, three main objectives were recognized:

1. Protection and management of the groundwater resources of British Columbia for present and future use.
2. Protection of the health, safety and welfare of the public who use the groundwater resource.
3. Protection for the consumer to ensure he has adequate potable water at reasonable cost.

The first initiative was taken in 1972 by the British Columbia Water Well Drilling Association who were responsible for a publication entitled *Minimum Specifications Domestic Water Wells* prepared by Mr. W.L. Brown, P. Eng., Groundwater Geologist. Subsequently, the Ministry of Environment, Water Management Branch, Groundwater Section, assumed the responsibility for preparing guidelines covering all types of well construction and well testing in the Province.

A first draft of the guidelines was completed in March 1978 and this was followed by a comprehensive process of referral. Therefore, the guidelines for minimum standards contained herein substantially represent the consensus recommendations of Provincial Government Agencies, the British Columbia Water Well Drilling Association, Professional Groundwater consultants and many others concerned with the management, development, protection and use of the groundwater resource.

Although reflecting current conditions and requirements, it is recognized that these guidelines will require on-going amendment in response to changing technology. The Ministry of Environment anticipates that this process will be facilitated by continuing input from all concerned.

In preparing *Guidelines for Minimum Standards in Water Well Construction — Province of British Columbia,* Ministry of Environment staff first undertook to review water well construction standards in other Provinces and States. An in-depth review was also made of the U.S. Environmental Protection Agency's Publication EPA-570/9-75-001 "Manual of Water Well Construction Practices." We wish to acknowledge the considerable use which was made of material on well construction standards published by other Provinces and States and especially the EPA manual for formulating our present guidelines. The EPA manual was prepared under the auspices of the National Water Well Association Committee on Water Well Standards comprised of thirty-four prominent technical and well contractor members of the groundwater industry, including representatives from state regulatory agencies. We also wish to acknowledge the use of material from eight other publications:

1. Manual of Water Well Construction Practices for the State of Oregon — Oregon Drilling Association Inc.
2. Groundwater & Wells published by Johnson Division, UOP Inc. St. Paul, Minnesota.
3. AWWA Standard for Deep Wells published by American Water Works Association, Park Avenue, New York. AWWA A100-66.
4. Practical Information on Groundwater Development — Ministry of Environment.
5. Annual Book of A.S.T.M. Standards.
6. Water Well Handbook — Missouri Water Well & Pump Contractor's Ass'n. Inc.
7. Manual on the Selection and Installation of Thermoplastic Water Well Casing — Produced by the National Water Well Association and the Plastic Pipe Institute.
8. Standard Specifications for Thermoplastic Water Well Casing Pipe and Couplings made in Standard Dimension Ratios (SDR). ASTM F480-76.

The Ministry of Environment, also acknowledges with appreciation, the considerable contribution made to the guidelines by staff of other Ministries, the special Standards and Licensing committee of the British Columbia Water Well Drilling Association under the chairmanship of Mr. R.F. McNichol, members of the Professional and Technical Section and members at large of the B.C.W.W.D.A., consultants in the groundwater field and the many other individuals who participated in the process.

2. GENERAL GUIDELINES FOR WATER WELL CONSTRUCTION

2.1 Preamble

Before deciding on a procedure to follow in constructing a water well, two factors

should first be considered (i) the type of well desired and (ii) the method of construction to be used.

Water Wells can be broadly classified into five main types:

(a) Dug or Pit Wells
(b) Radial Collector Wells
(c) Naturally Developed Screened Wells
(d) Artificial Filter Pack Wells
(e) Open Hole — Partially Cased Wells

To help determine the type of well needed to obtain the amount of water required it is helpful to have information on subsurface conditions at a given site, including the character and the depth of water producing zones and of overlying formations and on the proximity of existing or possible future sources of pollution. This knowledge together with information on relative construction costs will assist in determining the best construction method to use.

Well construction methods are many and varied and range from simple digging with hand tools to the use of high speed sophisticated drilling equipment. The most common construction methods are listed below:

(a) Digging
(b) Boring
(c) Driving
(d) Jetting and Hydraulicing
(e) Cable Tool
(f) Conventional Fluid Rotary Drilling
(g) Reverse Circulation Drilling
(h) Air Rotary Drilling
(i) Down Hole Hammer
(j) Top Drive Air Rotary with Casing Hammer

Further details on types of wells and well construction methods are given in Appendix No. 9.

For those readers who are not conversant with well construction, and groundwater development, there is a publication available which gives a brief introduction to the subject entitled *Practical Information on Groundwater Development.* Single copies can be obtained from the Ministry of Environment, Victoria, British Columbia.

2.2 Well Site Locations

A well should be located on higher ground so that the well head can be protected from normal flooding and surface drainage. Shallow wells should be located away from surface drainage ditches. The distance a well should be located from a possible source of contamination such as a tile field, septic tank, refuse dump, land fill, cemetary, effluent discharge, drainage ditch, etc., will depend on a number of factors. These factors include the nature and the source of contamination, the topography, topographic gradient, the hydrogeological conditions at the site area, nature of the aquifer (bedrock fractures, overburden, etc.), thickness of overlying impermeable beds if any, nature of the ground water flow system, the potential for dilution of the contaminant, the point in the groundwater flow system where the well is to be located, i.e., is it in a groundwater discharge zone or a recharge zone, is the well a flowing artesian, non-flowing artesian or water table well, etc.

In view of these factors which may vary from site to site, the selection of an arbitrary "standard" minimum distance at which a well should be located from a possible source of pollution, will not necessarily provide the required protection from well contamination.

Information about effluent disposal sites in a specific area can be obtained from the local Public Health Inspector.

Specified "minimum distances" can be found in Sanitary Regulations and Sewage Disposal Regulations under the British Columbia Health Act.

Although Sanitary Regulation No. 42* under the British Columbia Health Act relates to minimum distances between a well and potential sources of contamination, of necessity this distance may be often unnecessarily conservative and therefore the drilling contractor should consult the local Public Health Inspector in the interpretation thereof where special circumstances prevail.

2.3 Sanitary Protection of Wells

All dug wells should have an effective seal with grout to a depth of 15 feet or within 3 feet of the bottom of wells less than 18 feet deep. The seal should be at least 4 inches thick around the upper steel or cement well casing. The well head construction must insure that no contaminant can enter the well. See also Section 11 of these guidelines.

All jetted or driven wells should have an effective surface seal of grout, however due to the method of well construction it may not be possible to provide an effective seal to a depth of 15 feet. Special care must therefore be taken in the siting of such wells constructed by these methods. Drilled well completions in general should follow

* Sanitary regulation No. 42 stipulates among other things that a well must be located at least 100 feet from any probable source of contamination. Readers are referred to this regulation or to the Health District for further details.

the AWWA standard for deep wells to ensure contamination does not enter the well. The AWWA publication lists eleven types of drilled wells and gives details for construction and sealing to be employed for different conditions encountered.

As a general guideline it is recommended that all drilled wells be constructed with a surface grout seal to a minimum depth of 15 feet. However, for any specific case the grout seal depth must be deep enough to prevent the entrance of surface water or undesirable subsurface waters into the well.

In cases where there is a possibility for contamination of wells drilled into bedrock or for drilled wells penetrating clay, hardpan or other relatively stable unconsolidated material, a cement grout seal is recommended which extends from surface through these formations and in the case of a bedrock well, extending 15 feet down into the bedrock.

For further information see Appendix No. 3 — 2. Grouting Materials and 3. Methods of Installation of Grout.

2.4 Artesian Conditions

Where flowing artesian conditions are known or expected within the drilling depth, a method of construction using casing should be adopted to the depth of the impermeable layer overlying the artesian aquifer. The casing should be adequately sealed in the impermeable layer so as to prevent surface and subsurface leakage from the artesian aquifer. The flowing well must be equipped with a valve to control the flow.

2.5 Water Well Drillers Report

The drilling contractor should obtain and record all information possible including the depth, the thickness, type of material and water yielding potential of formations encountered in drilling the well. A well log should be completed for all wells and test wells drilled in the Province on the approved Ministry of Environment well record form. Contractors are requested to submit copies of logs of all holes to the Ministry as soon as possible, together with any supplementary information obtained which, in the opinion of the contractor, should be considered in managing the groundwater resource.

2.6 Drilling Fluids

Fresh non-polluted water must be used for all drilling fluid preparations. Drilling fluid additives should comply with industry standards and practices and should be applied and used as recommended by the manufacturer. No toxic or dangerous substances are to be added to the drilling fluid at any time. The quality of the drilling fluid should be maintained by the contractor to protect water-bearing and potential water-bearing formations penetrated in the bore hole. All water used in construction of the well or admitted to the well should contain a minimum 50 ppm (mg/L) chlorine.

2.7 Temporary Capping

Wells that will not be placed immediately into service or which will be left uncompleted for any period or which will be removed from service temporarily, should be capped with a water-tight welded locked or threaded cap or equipped with some other type of "vandal-proof" cover. Casing should be terminated not less than one foot above the surrounding ground surface and the well head should be constructed in such a manner to insure that no potential contaminant can drain back toward the well.

3. GUIDELINES FOR WELL CASING SELECTION AND INSTALLATION

3.1 General Considerations

All well casing should be of new material or in like new condition. Casing must be of sufficient strength and composition to resist the pressure exerted by the surrounding materials and other forces imposed during installation, and to resist rapid corrosion by soil and water environments. It should be of the proper length to accomplish the purpose of providing a channel from the source to the surface through unstable formations and through zones of actual or potential contamination.

The thickness of well casing should be selected in accordance with good design practice and experience as applied to conditions found at the well site. All casing that is to be driven should be of steel. Casing that is placed in an oversized drill hole may be of other types of materials as noted in these guidelines. All joints in all casing should be water-tight. Joints in steel casing should be welded or screwed coupled joints. Casing joints should have the same structural integrity as the casing itself. Welded joints should be at least as thick as the wall thickness of the well casing and be fully penetrating. The standards of the American Welding Society should apply if metallic casing is welded. For threaded and coupled joints the couplings should be API, or equivalent and when made up-tight all threads should be buried in the top of the coupling.

3.2 Steel Casing

Recommended wall thicknesses for standard steel line pipe for various diameters for use in water wells are given in Table 1. *These thicknesses are taken from EPA's Manual of Water Well Construction*

Practices EPA-570/9-75-001, and are based on both the need for strength in various kinds of construction and resistance to corrosion. The AWWA provide more detailed tables and standards for wall thicknesses in the publication *AWWA Standard for Deep Wells.*

Due to the number of water well drillers in the Province who use thinner wall casing on domestic wells drilled, especially by the rotary method and from discussions with BCWWDA members, it would appear that a wall thickness of 0.188 inches may be successfully used for wells up to and including 6.625 inches O.D. It is recommended this wall thickness only be used *provided the well is drilled by the rotary method and provided the casing is not driven.* Table No. 1 has therefore been amended to include a footnote to accommodate this revision.

Based on the combined, reported experience of its members, the British Columbia Water Well Drilling Association consider that, where ideal site conditions prevail and in the interests of initial economy, the minimum thicknesses for steel casing given in Table 2 can be accepted. The site-specific decision as to whether to use Table 1 or Table 2 thicknesses for steel casing must be predicated upon accepted design practice applied to known site conditions.

3.3 Thermoplastic Water Well Casing

All materials used for wells should meet or exceed the standards set for that material and purpose by the Canadian Society for Testing Materials (CSTM) or the American Society for Testing Materials (ASTM). Thermoplastic water well casing should only be installed in an over-sized drill hole and it must never be driven.

The type and diameter of thermoplastic water well casing to use for a particular job will include consideration of the following:

1. Required internal diameter to accommodate the pump.
2. Nature of the formations.
3. Total well depth.
4. Anticipated drawdown.
5. Techniques of installation including backfilling techniques and method of grouting.
6. Temperature.
7. Techniques of well development.

Tables 3 and 4 give guidelines for the *minimum* wall thickness and *maximum* recommended depths of use for three types of thermoplastic water well casing (PVC 12454, ABS 434 and SR 4434), for four standard dimension ratios (SDR 26, 21, 17 and 13.5) listed in the ASTM F480 specifications.

The 1981 NWWA Manual on Thermoplastic Water Well Casing (see Appendix 11) recommends that a casing be

TABLE 1

WALL THICKNESSES FOR STANDARD STEEL LINE PIPE RECOMMENDED FOR USE IN WATER WELLS*

Nominal Size in Inches	External Diameter In Inches	Internal Diameter In Inches	Wall Thicknesses In Inches	Weight in Pounds Per Foot	
				Plain Ends	Threads & Collars
2	2.375	2.067	0.154	3.56	3.71
2½	2.875	2.469	0.203	5.79	5.88
3	3.500	3.068	0.216	7.58	7.67
3½	4.000	3.548	0.226	9.11	9.27
4	4.500	4.026	0.237	10.79	11.01
5	5.563	5.047	0.250	14.62	14.90
6	6.625	6.065	0.250	18.97	19.33
8	8.625	8.071	0.250	24.70	25.44
10	10.750	10.192	0.279	31.20	32.20
12	12.750	12.090	0.330	43.77	45.40
14	14.000	13.250	0.375	54.57	55.80
16	16.000	15.250	0.375	62.58	64.08
18	18.000	17.250	0.375	70.59	72.37
20	20.000	19.250	0.375	78.60	80.70

* 0.188 inch well casing thickness is acceptable for wells up to and including 6-5/8 inches O.D., provided the well is drilled by the rotary method, and provided the *casing is not driven.*

TABLE 2

MINIMUM THICKNESSES FOR STEEL CASING RECOMMENDED BY THE B.C.W.W.D.A.

Nominal Size in Inches	Outside Diameter in Inches	Wall Thickness in Inches	Weight in Pounds Per Foot
1½	1.900	.109	2.08
2	2.375	.109	2.64
2½	2.875	.120	3.53
3	3.500	.125	4.51
4	4.500	.188	8.66
6	6.625	.188	12.89
8	8.625	.250	22.36
10	10.750	.250	28.04
12	12.750	.250	33.38
14	14.000	.312	45.61
16	16.000	.344	62.85
18	18.000	.375	70.59
20	20.000	.375	78.60
Over 20		.375	

selected so that its resistance to hydrostatic collapse is significantly larger than that required to resist external hydrostatic pressure alone, and in Tables 3 and 4 below, a recommended safety factor of 2 is used in computing the maximum recommended depth of use for three types of thermoplastic water well casing.

In the final analyses the depths to which thermoplastic water well casing can be used is a design judgement. A well casing with adequate packing to support the casing and to prevent casing deformation will allow placement to greater depths as long as the drawdown or head differential before packing is in place will always be within design limits.

All thermoplastic water well casing pipe couplings should meet the designated dimensional requirements given in ASTM F480 and the procedures for assembly should conform to that standard. All joints must be water-tight and where bell type ends or moulded couplings are used, all joints should be made utilizing solvent cement in accordance with the manufacturers directions. Threaded thermoplastic water well casing pipe couplings should be of the moulded or formed threads type only. The thread lubricant sealant specifically recommended for use with the designated thermoplastic material should be employed.

Further information on thermoplastic water well casing is given in Appendix No. 11.

3.4 Casing Diameter

The minimum water well casing inside diameter recommended for line shaft turbine pumps is 6 inches, where a submersible pump is used the minimum inside casing diameter recommended is 4 inches. The well casing should be straight and plumb enough (see Appendix No. 1) to allow for the setting and correct operation of a pump capable of delivering the required water supply.

The selected diameter of the well should be adequate to accommodate the size of pump necessary to supply the designed quantity of water, keeping in mind the efficiency of the pumping unit, the expected pump life, the extra clearance required in the event the casing is not exactly straight and the possibility of weld metal projecting inside at the joints of steel casing. As a general guide the diameter of the well casing should be two nominal sizes larger than the bowl size of line shaft turbine pumps and in no case should it be less than one nominal size larger. Tables 5 and 6 have been prepared to show well casing sizes recommended for line shaft turbine pumps for wells ranging from under 100 U.S. gpm to over 4,500 U.S. gpm.

3.5 Casing Seating

It is common practice to drive a single steel casing into bedrock without first enlarging the hole and attempting to obtain a good grout seal. In cases where there is a

TABLE 3

MINIMUM WALL THICKNESSES & MAXIMUM RECOMMENDED DEPTH OF USE FOR THREE TYPES OF THERMOPLASTIC WATER WELL CASING (PVC 12454, ABS 434 & SR 4434) FOR TWO STANDARD DIMENSION RATIOS (SDR 26, SDR 21) LISTED IN ASTM F480 SPECIFICATIONS

	SDR 26 Minimum Specifications for Thermoplastic Water Well Casing Up to a Depth of 70 ft.						SDR 21 Minimum Specifications for Thermoplastic Water Well Casing Up to a Depth of 130 ft.					
Nominal Diameter In Inches Of Casing Sizes Covered By These Guidelines	Casing Sizes[5] in Inches, Covered by These Guidelines			Maximum Recommended[1] Depth of Use for Three Types of Thermoplastic Casing in SDR 26			Casing Sizes[5] in Inches, Covered by These Guidelines			Maximum Recommended[1] Depth of Use for Three Types of Thermoplastic Casing in SDR 21		
	Average Outside Diameter	Minimum Inside Diameter[4]	Minimum Wall Thickness	PVC 12454	ABS 434	SR 4434	Average Outside Diameter	Minimum Inside Diameter[4]	Minimum Wall Thickness	PVC 12454	ABS 434	SR 4434
2	—	—	—				2.375	2.05	0.113	130 ft.	115 ft.	100 ft.
2½	—	—	—				2.875	2.51	0.137	130 ft.	115 ft.	100 ft.
3	—	—	—				3.500	3.05	0.167	130 ft.	115 ft.	100 ft.
3½	—	—	—				4.000	3.49	0.190	130 ft.	115 ft.	100 ft.
4	4.500	4.01	0.173	70 ft.	60 ft.	50 ft.	4.500	3.92	0.214	130 ft.	115 ft.	100 ft.
5	5.563	4.95	0.214	70 ft.	60 ft.	50 ft.	5.563	4.85	0.265	130 ft.	115 ft.	100 ft.
6	6.625	5.90	0.255	70 ft.	60 ft.	50 ft.	6.625	5.72	0.316	130 ft.	115 ft.	100 ft.
8	8.625	7.68	0.332	70 ft.	60 ft.	50 ft.	8.625	7.52	0.410	130 ft.	115 ft.	100 ft.
10	10.750	9.58	0.413	70 ft.	60 ft.	50 ft.	10.750	9.37	0.511	130 ft.	115 ft.	100 ft.
12	12.750	11.35	0.490	70 ft.	60 ft.	50 ft.	12.750	11.13	0.606	130 ft.	115 ft.	100 ft.
14	14.000	12.47	0.539	70 ft.	60 ft.	50 ft.	14.000	12.21[3]	0.667[3]	130 ft.	115 ft.	100 ft.
16	16.000	14.25	0.616	70 ft.	60 ft.	50 ft.	16.000	13.95[3]	0.762[3]	130 ft.	115 ft.	100 ft.
Hydraulic Collapse Pressure[2]												
Lbs. per square inch				59	51	47				115	100	92
Ft. (head) of water				136	118	109				265	231	212

[1] NWWA Manual on Thermoplastic Water Well Casing, recommends that a sufficient margin be provided against possible collapse by all normally anticipated external loadings. A casing should be selected so that its resistance to hydrostatic collapse is significantly larger than that required to resist external hydrostatic pressure alone. The above table uses the recommended factor of safety of approximately × 2. Larger factors should be used when it is apparent that greater weight should be given to the other external loadings.

[2] From values calculated in NWWA Manual on Thermoplastic Water Well Casing.

[3] These sizes are under consideration by ASTM for addition to ASTM F480.

[4] From values given in NWWA Manual of Thermoplastic Water Well Casing. These minimum inside diameters assume an average wall thickness of six percent above the specified ASTM minimum.

[5] As given in ASTM F480 and NWWA Manual on Thermoplastic Water Well Casing.

TABLE 4

MINIMUM WALL THICKNESSES & MAXIMUM RECOMMENDED DEPTH OF USE FOR THREE TYPES OF THERMOPLASTIC WATER WELL CASING (PVC 12454, ABS 434 & SR 4434) FOR TWO STANDARD DIMENSION RATIOS (SDR 17, SDR 13.5) LISTED IN ASTM F480 SPECIFICATIONS

	SDR 17 Minimum Specifications for Thermoplastic Water Well Casing Up to a Depth of **250 ft.**						SDR 13.5 Minimum Specifications for Thermoplastic Water Well Casing Up to a Depth of **540 ft.**					
Nominal Diameter In Inches Of Casing Sizes Covered By These Guidelines	Casing Sizes[5] in Inches, Covered by These Guidelines			Maximum Recommended[1] Depth of Use for Three Types of Thermoplastic Casing in SDR 17			Casing Sizes[5] in Inches, Covered by These Guidelines			Maximum Recommended[1] Depth of Use for Three Types of Thermoplastic Casing in SDR 13.5		
	Average Outside Diameter	Minimum Inside Diameter[4]	Minimum Wall Thickness	PVC 12454	ABS 434	SR 4434	Average Outside Diameter	Minimum Inside Diameter[4]	Minimum Wall Thickness	PVC 12454	ABS 434	SR 4434
2	2.375	2.01	0.140	250 ft.	225 ft.	200 ft.	2.375	1.94	0.176	540 ft.	475 ft.	430 ft.
2½	2.875	2.44	0.169	250 ft.	225 ft.	200 ft.	2.875	2.35	0.213	540 ft.	475 ft.	430 ft.
3	3.500	2.97	0.206	250 ft.	225 ft.	200 ft.	3.500	2.86	0.259	540 ft.	475 ft.	430 ft.
3½	4.000	3.40	0.235	250 ft.	225 ft.	200 ft.	4.000	3.27	0.296	540 ft.	475 ft.	430 ft.
4	4.500	3.82	0.265	250 ft.	225 ft.	200 ft.	4.500	3.68	0.333	540 ft.	475 ft.	430 ft.
5	5.563	4.73	0.327	250 ft.	225 ft.	200 ft.	5.563	4.55	0.412	540 ft.	475 ft.	430 ft.
6	6.625	5.51	0.390	250 ft.	225 ft.	200 ft.	6.625	5.41	0.491	540 ft.	475 ft.	430 ft.
8	8.625	7.32	0.508	250 ft.	225 ft.	200 ft.	—	—	—			
10	10.750	8.58	0.632	250 ft.	225 ft.	200 ft.	—	—	—			
12	12.750	10.82	0.750	250 ft.	225 ft.	200 ft.	—	—	—			
14	—	—	—				—	—	—			
16	—	—	—				—	—	—			
Hydraulic Collapse Pressure[2]												
Lbs. per square inch				224	196	180				470	412	376
Ft. (head) of water				517	453	416				1086	952	869

[1] NWWA Manual on Thermoplastic Water Well Casing, recommends that a sufficient margin be provided against possible collapse by all normally anticipated external loadings. A casing should be selected so that its resistance to hydrostatic collapse is significantly larger than that required to resist external hydrostatic pressure alone. The above table uses the recommended factor of safety of approximately × 2. Larger factors should be used when it is apparent that greater weight should be given to the other external loadings.

[2] From values calculated in NWWA Manual on Thermoplastic Water Well Casing.

[3] These sizes are under consideration by ASTM for addition to ASTM F480.

[4] From values given in NWWA Manual of Thermoplastic Water Well Casing. These minimum inside diameters assume an average wall thickness of six percent above the specified ASTM minimum.

[5] As given in ASTM F480 and NWWA Manual on Thermoplastic Water Well Casing.

TABLE 5
CASING SIZES RECOMMENDED FOR LINE SHAFT TURBINES (1800 RPM)

Yield	Recommended Casing Size
Less than 100 USgpm	6" I.D.
75 - 175 USgpm	8" I.D.
150 - 400 USgpm	10" I.D.
350 - 600 USgpm	12" I.D.
600 - 1300 USgpm	16" O.D.
1300 - 1800 USgpm	20" O.D.
1800 - 3000 USgpm	24" O.D.
3000 - 4500 USgpm	30" O.D.
Over 4500 USgpm	30" O.D.

TABLE 6
CASING SIZES RECOMMENDED FOR LINE SHAFT TURBINES (1200 RPM)

Yield	Minimum Recommended Casing Size
1200 - 1800 USgpm	20" O.D.
1800 - 3000 USgpm	24" O.D.
3000 - 4500 USgpm	28" O.D.
Over 4500 USgpm	30" O.D.

possibility for contamination, the use of a single casing is not recommended for wells drilled into bedrock or for wells penetrating clay, hardpan or other relatively stable unconsolidated material. Under these conditions it is very hard to get a tight seal between the single casing and the formation with the result that potential contaminants may enter the well. An adquate grout seal can be obtained by first drilling and installing an oversized surface casing which can later be withdrawn as the grout is placed around the inner casing. For further information see Appendix No. 3 — 3.2 Methods of Drilled Well Construction to Provide an Adequate Grout Seal Around the Well Casing and 3.3 Methods of Grouting the Annular Space Surrounding a Well Casing.

4. GUIDELINES FOR WELL SCREENS AND ARTIFICIAL FILTER PACK CONSTRUCTION

4.1 General Considerations

It is recommended that wells drilled into unconsolidated formations be completed using a well screen from a recognized manufacturer. Information on screens, aperture size selection and when to use an artificial filter pack around the well screen are given in Appendix No. 2. For domestic wells under certain conditions when the water-bearing formation consists of gravel, slotted casing or an open bottom construction can very occasionally be used with drilled wells provided the well does not pump sand.

5. GUIDELINES FOR WELL GROUTING

5.1 General Conditions

Grouting is required for:

(a) i. Aquifer protection: to stop groundwater movement between aquifers.
ii. Well protection: to stop unwanted water entering from the *surface* or a subsurface zone.
iii. Casing protection: for example, where corrosive water can attack the casing in certain zones.

(b) It is most important that the annular space be sealed to a sufficient depth (15 or more feet depending on conditions) to prevent contamination or pollution by surface waters or shallow subsurface waters where there may be effluent from septic tanks, etc.

(c) Formations encountered during well construction which are yielding

groundwater of undesirable quality must be adequately sealed off from underlying (or overlying) water-bearing zones.

Details on grouting are given in Appendix No. 3.

6. GUIDELINES FOR WELL DEVELOPMENT

6.1 General Considerations

An important factor in well development is that the development work be started slowly and gently and increased in vigor as the well is developed.

When to stop well development is to a large extent a matter of experience and judgement; periodic pumping or bailing will indicate whether the sand content in the well is decreasing and whether for a given rate of flow and period of test the drawdown becomes less as well development proceeds.

6.2 Water for Well Development

Under no circumstances should water be introduced into a well for jet development, etc., that does not meet the recommended water quality standards published by the Provincial Ministry of Health, without prior approval from the local health officer.

6.3 Acids or Other Chemicals

If acids or other chemicals are introduced into the well to develop the well, the well water should be pumped until all traces of the chemical are dissipated, before being connected up to a piped system.

6.4 Sand Content

The contractor should attempt to meet the following recommended limits for sand content in well water:

(a) Sprinkler systems, industrial evaporative cooling systems and other uses where a moderate amount of sand is not especially harmful — 10 ppm (mg/L).

(b) Wells supplying water to be used directly in contact with or on the processing of food or beverages — 1 ppm (mg/L).

(c) Wells supplying water to homes, institutions, municipalities and industries — 5 ppm (mg/L).

Information on Well Development Methods is given in Appendix No. 4.

7. GUIDELINES FOR WELL TESTING

7.1 Water Wells for Single Family Dwellings (Domestic Wells)

Domestic water wells should be test pumped, bail tested or air lifted for a *minimum* of one hour following construction of the well. The static water level should be recorded prior to testing, the change in water level within the well should be recorded if possible, and recovery measurements taken to give some idea of well capacity. Domestic wells constructed in bedrock require a longer test period.

In testing a well by means of a simple bail or air lift test, the amount of water taken out in a given time has to be approximated. However, when a well is test pumped there are several procedures that can be used to obtain information on well capacity.

Firstly, a step-drawdown test may be used. In this procedure, the well is pumped at several rates starting with a minimum rate and increasing in several "steps" to the maximum rate desired. Each step is continued until the level in the well becomes approximately stable, or until the rate of decline of water level becomes constant. Secondly, a constant rate test can be run. In this case the well discharge should remain constant for the duration of the test.

A recovery test may also be used. Here the well is pumped at a fixed rate for a number of hours during which the level in the well is observed. Pumping is stopped abruptly and the water level is recorded as the water level rises in the well. In using this method it is important to record the time of starting and stopping of pumping and the time of all observations, and it is particularly important to observe the last part of the well recovery as it approaches the original level. This may mean taking observations for many hours after pumping has been stopped. The following two tables (Tables 7 and 8) illustrate the type of information recorded in pumping and recovery tests.

For domestic water wells constructed in bedrock, longer more sophisticated tests may have to be undertaken and where only a one hour minimum bail test, pump test or air lift test is done followed by the recovery test, the well owner should be informed that the yield may differ considerably from the test result obtained, particularly during summer drought conditions.

Pump testing of wells constructed in fractured bedrock must be done with considerable care. Experience shows, that the amount of water entering a well from fractures during sustained pumping usually decreases before becoming approximately constant. Rock wells should be pumped for a long period (usually more than two days) at a *constant rate* in order to detect the decrease in well capacity with time.

In testing rock wells at locations where

TABLE 7
PUMPING TEST

Depth to water in well from top of casing before test _____ ft.

Time	Time Since Start of Pumping (Minutes)	Depth to Water in Well from Top of Casing (Feet)	Discharge from Well (Gallons/Minute)

For the above table, readings should be taken every minute from 1 to 10 minutes and then every 10 minutes from 10 to 120 minutes (2 hours), then readings every 1½ hours thereafter.

TABLE 8
RECOVERY TEST

Time	Time Since Start of Pumping (Minutes)	Time Since Pumping Stopped (Minutes)	Depth to Water in Well from Top of Casing (Feet)

For the above table, readings should be taken every minute from 1 to 10 minutes and then every 10 minutes from 10 to 120 minutes (2 hours), then readings every 1½ hours thereafter. Slow recovery may require that the last readings be spaced as much as 8 to 12 hours apart.

the distribution of rainfall is very uneven throughout the year and where the well is fairly close to its source of recharge, the results of pump testing may vary considerably with the season. For example, certain wells located on the Gulf Islands of British Columbia, where there is normally a long, dry summer, show lower capacity when tested in early aûtumn than when tested in winter.

7.2 **Industrial, Irrigation and Community Water Supply Wells**

Large capacity wells for industrial or irrigation use should be test pumped at rates at least equal to the expected pumping rate for a period of up to 24 hours, or for a longer time period in certain circumstances as in the case of wells constructed in fractured bedrock. The pumping rate should be held constant during the final pumping test and the reader is referred to the tables in Appendix No. 5 for the type of information to be recorded in pumping and recovery tests. In large capacity wells, a pumping test for maximum information may include one or more observation wells near the well being pumped, and this test is frequently run under the supervision of a consulting groundwater geologist or a professional engineer, whose field of competence lies within the groundwater field. In this test the observation well(s) should, of course, be in the same aquifer as the pumped well. In this procedure, pumping is started at a steady rate which is sustained for at least several hours. The drawdown is measured in observation wells and in the pumped well at frequent intervals during the pumping. Tests may be conducted at several different pumping rates. The analyses of these pumping data are rather involved. A number of assumptions are made concerning the nature of the aquifer, flow to the well and other factors. These assumptions may not be correct, but they are usually close enough to give an approximate idea of the conditions

prevailing. The analyses determines aquifer constants called "Transmissivity" and "Coefficient of Storage." These measure the ability of the aquifer to transmit and store water. From the aquifer constants, predictions can be made concerning well yield drawdowns at various distances from the well and other factors. In this type of test, the performance of the well may be separated from the performance of the aquifer.

For community water supply wells, instruction and procedures for preparation of groundwater reports and for undertaking well tests in support of a Certificate of Public Convenience and Necessity, see Appendix No. 5. Further information should also be obtained from the Water Management Branch of the Ministry of Environment.

8. GUIDELINES FOR WELL DISINFECTION

8.1 General Considerations

All wells should be disinfected by the drilling contractor following completion. The quantity of chlorine compounds used for disinfection should be sufficient to produce a 50 ppm chlorine solution when thoroughly mixed with the total volume of water retained within the well.

Following installation of the pump and fittings, the pump installer should further chlorinate the well to 50 ppm, making sure the chemical is thoroughly mixed within the well. Before being used for consumption the chlorine solutions should be pumped to waste and until the smell of the chlorine has dissipated. To protect aquatic life or vegetation, the disposal point for the waste water from the well must be carefully selected.

Further information on well disinfection can be obtained by referring to Appendix No. 6 and the local health district.

9. GUIDELINES FOR WATER SAMPLES AND ANALYSES

9.1 General Considerations

Water in all wells should be sampled and the necessary field and laboratory tests made so that the groundwater chemical and bacteriological quality of each well and its suitability for its intended use can be determined. Recommended Water Quality Standards have been published by the Provincial Ministry of Health for drinking water and the reader is referred to this publication and the local Medical Health Officer for further details. The Ministry of Health should be contacted for advice on what additional analyses may be required and on any consitituents present in well waters which are above the recommended safe limits. All proposals for sampling and analyses for public drinking water supplies serving more than one single family residence should be reviewed by the Medical Health Officer.

For chemical analyses, sample collection procedures vary from the use of a bailer common to the cable tool method to more sophisticated samplers which can take a water sample at a specific depth. Usually samples are collected from the discharge during test pumping or after the production pump is installed. A list of recommended parameters for chemical analyses and further details on water quality are given in Appendix No. 7, and in the Ministry of Environment publication entitled *Practical Information on Groundwater Development.*

A sample should be taken on all wells to determine bacteriological quality. For new or repaired wells AWWA A100-66 recommends the collection of any sample for determination of bacteriological quality be taken *following* the disinfection of the well. Chlorine solution must first be removed from the well by pumping, and the chlorine residual reduced to less than 2 ppm before the sample is taken.

The local public health inspector should be requested to obtain a sample for bacteriological analyses where the water is to be used for a public water supply system. In situations where this is not possible, sample bottles and advice on sampling techniques may be obtained through the local health district.

The quality of any drinking water supply cannot be determined with confidence from the result of a single sample, but rather is possible only by observing the results of several samples over a long period of time. Shallow wells that may be influenced by surface contamination near the well may produce water of varying quality depending on climatic and physical conditions. Therefore, if a sanitary survey shows a well water supply to be obviously subject to pollution, the water may be condemned, irrespective of the test results.

10. GUIDELINES FOR PERMANENT WELL, TEST WELL AND TEST HOLE ABANDONMENT

10.1 General Considerations

All test holes, test wells, mineral drill holes and abandoned water wells should be sealed in such a way as to protect any aquifers penetrated. The sealing material should be safe from a health point of view and be more impervious than the material encountered during the drilling of the hole.

Accurate records should be kept of all abandoned holes showing their location,

the well log and the methods and materials used in the abandonment procedure.

Because of the complexities involved in some cases of well abandonment, each case should be considered as an individual problem and the design, construction of the well and the hydrogeology must be considered and studied before final selection of materials, methods and procedures can be realized. It would be wise, where there is doubt as to the well construction or the hydrogeology, to adopt those materials and procedures which will give the greatest possible chance for a successful and permanent sealing operation.

Further information on permanent well, test well and test hole abandonment is given in Appendix No. 8.

11. GUIDELINES FOR WELL HEAD COMPLETIONS AND PUMP INSTALLATIONS*

11.1 General Considerations

(a) All pump installations which involve below-surface well-head works should include waterproof pitless adapters or waterproof drained pits. (Further information on pitless adapters is given in Appendix No. 10.)

(b) The well casing should not be cut off below ground surface unless it is enclosed in a waterproof drained pit and fitted with an enclosing cap.

(c) The well-head should be finished in such a way to ensure that all water flows away from the well-head.

(d) To prevent backflow into any well it is good practice to install a swing-check valve or a backflow preventer on the well-head pipework. To minimize surge pressures on pump start up or shut down, a pump control valve should be fitted. The prevention of backflow is *essential* where the well is to be used for filling containers or where the potential for contaminated backflow is particularly significant.

(e) Pumps should not be in contact with the well screen and large capacity pumps should be installed in a manner which allows the weight of the pump and/or column to be fully supported at the surface on a foundation independent of the well casing.

(f) All well-pump-installations should include provision for venting air from and into the well and the well-head pipework, and for taking water level soundings in the well.

(g) Metering facilities are essential in order to effectively monitor the performance of the well and pump. All wells used for industrial and public water supply should be equipped with a suitable water meter.

(h) Provision should be made in the pump house design for maintenance equipment, drilling rigs, etc. to operate at the well head in case it is necessary to redevelop or remove the pump, etc.

(i) Thermoplastic water well casing should be protected by steel casing at the ground surface in such a way as to prevent damage to the plastic. The steel casing must be firmly anchored into the ground.

* See also 2.3 — Sanitary Protection of Wells

TABLE 9

U.S. - IMPERIAL - METRIC (SI) FACTORS

To Convert	To	Multiply By
inches (in)	centimetres (cm)	2.540
feet (ft)	metres (m)	0.3048
miles (mi)	kilometres (km)	1.609
square miles (mi^2)	square kilometres (km^2)	2.590
cubic feet/second (cfs)	litres/second (L/s)	28.32
Imperial gallons (Ig)	litres (L)	4.546
Imperial gallons/day (Igpd)	litres/second (L/s)	5.261×10^{-5}
Imperial gallons/day/ft^2 (Igpd/ft^2)	metres/second (m/s)	5.663×10^{-7}
Imperial gallons/day/ft (Igpd/ft)	square metres/second (m^2/s)	1.726×10^{-7}
Imperial gallons/min (Igpm)	litres/second (L/s)	7.576×10^{-2}
U.S. gallons (USg)	litre (L)	3.785
U.S. gallons/day/ft^2 (USgpd/ft^2)	metres/second (m/s)	4.720×10^{-7}
U.S. gallons/day/ft (USgpd/ft)	square metres/second (m^2/s)	1.437×10^{-7}
U.S. gallons/min (USgpm)	litres/second (L/s)	6.309×10^{-2}
U.S. fluid ounces	litres (L)	2.95727×10^{-2}
Imperial fluid ounces	U.S. fluid ounces	9.6075×10^{-1}
Imperial gallons (Ig)	U.S. gallons (USg)	1.2

GUIDELINES FOR MINIMUM STANDARDS IN WATER WELL CONSTRUCTION PROVINCE OF BRITISH COLUMBIA

TECHNICAL INFORMATION APPENDICES

GUIDELINES FOR MINIMUM STANDARDS IN WATER WELL CONSTRUCTION — PROVINCE OF BRITISH COLUMBIA

PART 2

TECHNICAL INFORMATION APPENDICES

APPENDIX No. 1
WELL PLUMBNESS AND ALIGNMENT

1. INTRODUCITON

Well plumbness and alignment are never 100% in any well. Where the outside diameter of the pumping equipment is considerably smaller than the diameter of the well, plumbness and alignment seldom are a problem in a *shallow* well.

However, well plumbness and alignment become critical on deep holes and/or where a vertical turbine pump is to be permanently installed in the well. A vertical turbine pump may operate satisfactorily when considerably inclined from the vertical; however, when well alignment is badly out and there is also evidence of kinks, bends or corkscrews in the well, the well should be rejected because of the severe wear that can take place on pump shaft, bearings, and discharge casings. Also the pump may become stuck in the hole!

2. METHODS OF TESTING

Testing for plumbness and alignment tests are given in the AWWA standard for deep wells and also in EPA 570/9-75-001, the latter is reproduced below:

> "Alignment shall be tested by lowering into the well to the depth of the lowest anticipated pump setting, a section of pipe 40 feet long or a dummy of the same length. The outer diameter of the pipe or dummy shall be not more than ½ inch smaller than the inside diameter of that part of the casing or hole being tested when the casing diameter is a nominal 10 inches or less. When the nominal diameter of the casing being tested is 12 inches or greater, the outer diameter of the test pipe or dummy shall not be more than 1 inch smaller than the inside diameter of that part of the casing or hole being tested. The dummy when lowered into the casing shall pass freely the entire depth of the well.
>
> The test for plumbness shall be made with a plummet.

Construct a tripod or frame "B" similar to that shown in Figure 1. The center of the pulley "C" should be exactly 10 feet above the top of the well. The pulley must be so located that the plumb line "A" will come off its outer edge exactly over the center "D" of the well casing.

Make the plumb ring or plunger "E" ¼ inch smaller in diameter than the inside diameter of the well casing. It can be made from a piece of steel plate or a short piece of pipe. Whichever is used, it must be heavy enough to keep the plumb line taut. The hub of the ring must not be solid as the water must pass through it as it is lowered in the well. The hole "F" through which the plumb line "A" passes must be in the exact center of the ring. Knots or marks should be made every 10 feet on the plumb line, to indicate the depth the ring has been lowered in the well.

The well characteristics are determined by lowering the plumb ring 10 feet at a time and taking a reading at each location. If the plumb line passes exactly through the center line "D" at any location, the well is plumb at the depth the plumb ring is suspended. However, if the line "A" does not pass through "D," the well at that depth is out of plumb by an amount equal to distance "A" from "D" plus an equal distance for each 10 feet that the plumb ring "E" is below the floor level. For example, assume that "C" is exactly 10 feet above floor level and "D" is at floor level. If plumb line "A" is 1/16th of an inch from the center line of the well at "D" and the plumb ring "E" is 10 feet below the floor line, then the well is 1/8th of an inch out of plumb at the 10 foot level. If "A" is 1/16th inch from the

center of the well at "D" when the plumb ring "E" is 50 feet below the floor level at "D" then the well is 1/16th plus 5/16th, or 3/8th of an inch out of plumb at the 50 foot level. This is simply the proportion of similar triangles, and expressed in that way, variation from plumb equals,

$$\frac{60 \text{ ft.}}{10 \text{ ft.}} \times \frac{1}{16} \text{ inch} = \frac{6}{16} \text{ inch} = \frac{3}{8} \text{ inch}$$

This reading at the various depths tested may be plotted on cross section paper and an accurate diagram of the well developed."

It is recommended that the readings and plottings that are described above should be made on two planes 90° from each other so that the tendencies of the well to "corkscrew" or bow can be determined.

APPENDIX No. 2

WELL SCREENS AND ARTIFICIAL FILTER PACK CONSTRUCTION

1. WELL SCREENS

There are two basic types of wells in unconsolidated materials:

(i) naturally developed wells
(ii) artificially introduced filter pack wells

If the unconsolidated material is non-homogeneous, has a uniformity coefficient[1] *greater* than 3.0, and has an effective grain size[2] *greater* than 0.01 inches then a naturally developed well should be constructed.

The choice of well screen material should be selected on the basis of chemical analyses of the water or prior knowledge of the water quality. Where well treatment with strong chemicals may be required or where waters are corrosive or incrustation may be a problem, stainless steel is recommended. However, there are many situations where other materials will give very satisfactory results.

The well screen aperture openings, screen lengths and diameter should be selected so that sufficient open area is available to give the required well yield without exceeding an entrance velocity into the screens of 0.1 foot per second.

Screen sections can be joined together by welding or by threaded connections. The welding rod material must be suitable for joining corrosion resistant materials so as *not to reduce* that resistance. Where dissimilar metals are joined, a dielectric coupling can be used. Screen settings will depend on analyses of the unconsolidated formation aquifer materials, the driller's log, stratigraphic log and/or electric log if the latter two are available.

According to EPA 570/9-75-001, screen aperture size selection should be based on the following criteria:

A. Where the uniformity coefficient of the aquifer is greater than 6 and the aquifer is overlain by an essentially non-caving formation, the aperture size should be that which retains 30 percent of the aquifer sample.
B. Where the uniformity coefficient of the aquifer is greater than 6 and the aquifer is overlain by a readily caving formation, the aperture size should be that which retains 50 percent of the aquifer sample.
C. Where the uniformity coefficient of the aquifer is 3 or lower and the aquifer is overlain by an essentially non-caving formation, the aperture size should be that which retains 40 percent of the aquifer sample.
D. Where the uniformity coefficient of the aquifer is 3 or lower and the aquifer is overlain by a caving formation, the aperture size should be that which retains 60 percent of the aquifer sample.
E. For conditions between the extremes listed, the contractor should interpolate to obtain the proper screen aperture size.
F. Where a formation to be screened has layers of different grain sizes and graduations, use the following rule: If the 50 percent size of the coarsest layer is less than 4 times the 50 percent size of the finest layer, the aperture size should be selected on the basis of the finest layer, or for each specific layer as indicated in A, B, C, D, or E.
G. If the water is corrosive or the accuracy of the chemical analysis is in doubt, select an aperture size that will retain 10 percent more than is indicated in the above paragraphs.
H. Where fine sand overlies coarse sand, use the fine sand size aperture for the top two feet of the underlying coarse sand. The coarse size aperture should not be larger

[1] The uniformity coefficient is the size of sieve that retains 40% of the sample divided by the size that retains 90%.

[2] The effective grain size is the sieve size that retains 90% of the sample.

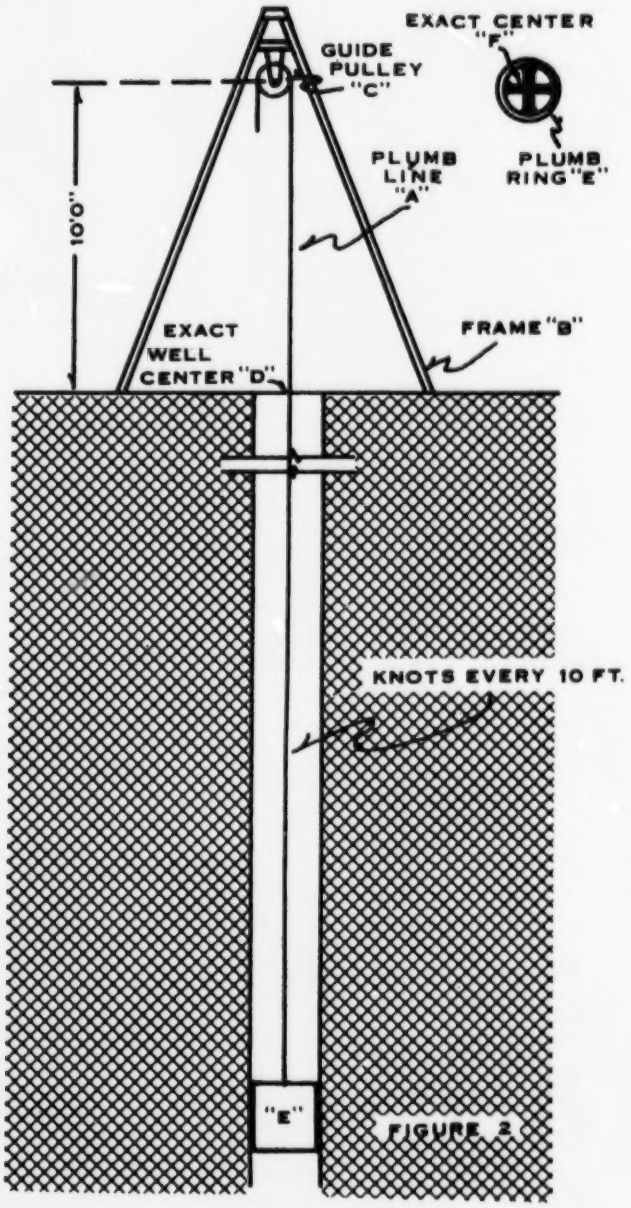

Figure 1
Well Plumbness Test Assembly
(reprinted from EPA 570/9-75-001)

than twice the fine sand size. For futher details on screen apertures size selection the reader is referred to the recognized text books and publications on the subject.

I. Where an artificial filter is to be used the aperture size selection criteria should be in accordance with Section 2 Artificial Filter Pack Construction.

Recommended methods of connecting screen to casing will depend on whether nominal or pipe size screen is used and the method of screen installation. Methods include neoprene or rubber seal and threaded, coupled or welded joints. Recommended methods of sealing the bottom of the screen include welded plate (screen material), fabricated plug threaded or welded (screen material), self closing valve, bag cement methods in extension pipe at bottom of screen.

2. ARTIFICIAL FILTER PACK CONSTRUCTION

2.1 Introduction

Well screens set within aquifers consisting of unconsolidated materials with a uniformity coefficient less than 3 and an effective grain size less than 0.01 inches are recommended to be surrounded by an artificial filter pack. According to EPA 570/9-75-001, an artificial filter pack consists of clean sand or gravel of selected grain sizes and gradations which is installed in the annular space between the screen and the wall of the well bore. The filter has a larger average grain size and usually a smaller coefficient of uniformity than the aquifer material. This permits use of a larger screen slot size and consequent larger open area so that entrance velocity is lowered and head losses to the well are reduced. The filter has a considerably higher permeability than the formation so that the effective diameter of the well is increased to some extent. Both these factors tend to increase the efficiency and specific capacity of a well and tend to reduce the possibility of excess sand production.

The grain size and gradation of the filter are selected to stabilize the aquifer material and to permit only the fine fractions to move into the well during development. Thus after development a correctly filtered well is relatively sand-free, and a narrow annulus of the formation adjacent to the filter has its permeability increased to some degree. Generally, the thinner the filter the better. Actually a correctly designed filter ½-inch thick would be adequate, but the mechanical difficulties of satisfactorily placing such a filter preclude its use. From a practical stand-point, filter packs are usually about 4 to 8 inches thick.

In a shallow well with 6 inches or more of annular space and 5 to 6 feet of screen the filter material can be easily dumped in to give a satisfactory installation. In deep wells with longer screens, to avoid bridging and segregation of the filter material, it should be placed with great care. If placed by gravity the material should be introduced at a metered, uniform rate. Frequently it is placed via a tremie pipe. Other practices include washing or pumping the filter material in with water (as a slurry) which is an effective way of placing the filter pack. Once installation of the filter material is started it should proceed at a uniform rate until completed from the bottom of the well to a selected point above the screen or perforations.

2.2 Selection of Artificial Filter Pack Grain Size and Screen Aperture Size

According to EPA 570/9-75-001 "The filter grain size should be determined by taking the 70 percent retained grain size of the finest formation to be filtered and multiplying it by 4, 5 or 6. This is the 70 percent retained grain size of the filter material to be used. The uniformity coefficient (the size of sieve that retains 40 percent of the sample divided by the size that retains 90 percent) should not be greater than 2.5. The gradation of the filter material should form a smooth and gradual size distribution curve when plotted. The screen aperture openings should be of such size as to retain between 85 and 100 percent of the filter material. The thickness of the filter should range from a minimum of 3 inches to approximately 8 inches."

2.3 Length of Artificial Filter Pack

In general the filter pack material should extend a distance of 2½ times the largest diameter of the well above any screen. Sand, cement or additional filter material should be placed between the filter material and the lower limit of the sanitary seal. The size of the sand should be such that it will not infiltrate into the filter material.

2.4 Storage of Filter Material

If the filter pack material is delivered in bulk it should be placed on a protective sheet to prevent contact with the ground and also covered.

2.5 Disinfection of Filter Material

Procedures for adequate disinfection are given under Well Disinfection (Appendix No. 6).

APPENDIX No. 3
WELL GROUTING

1. REQUIREMENTS

1.1 Grouting can be defined as filling a void with an impervious material.

1.2 Grouting is required for:

(a) Aquifer protection: to stop groundwater movement between aquifers and to maintain groundwater quality.

(b) Well protection: to stop unwanted water entering from the *surface* or a subsurface zone.

(c) Casing protection: for example, where corrosive water can attack the casing in certain zones.

1.3 It is most important that the annular space between formation materials and outer casing be sealed to a sufficient depth (15 or more feet depending on conditions) to prevent contamination or pollution by surface waters or shallow subsurface waters where there may be effluent from septic tanks, etc.

1.4 Polluted formations encountered during well construction which are yielding groundwater of undesirable quality must be adequately sealed off from underlying (or overlying) water-bearing zones.

2. GROUTING MATERIALS

2.1 Cement based materials can be used as grout. Neat cement (cement and water), sand cement, and concrete are generally easily obtained and mixed. Concretes find application where space to be filled is substantial for example, in some dug wells etc.

2.2 Clay should only be used as a sealant in well construction when drying out and washing away cannot occur. *Clay is defined in these guidelines as bentonite or equivalent commercial slurry, clay slurry, or puddled clay.*

Do not use clay when:

(a) Sealant will be in contact with the aquifer.

(b) When strength and stability are required.

(c) When the sealant may dry out.

(d) When flowing or moving water may break down the sealant.

(e) When cement grout is specified to be used as stated in these guidelines.

2.3 Concrete grout is mixed in the proportion of at least five (5) bags of Portland cement per cubic yard of concrete to not more than six (6) U.S. gallons of clean water per bag (one cu. ft. or 94 lbs.) of cement.

2.4 Sand cement grout is mixed in the proportion of not more than two parts by weight sand to one part of Portland cement with not more than six (6) U.S. gallons of clean water per bag (one cu. ft. or 94 lbs.) of cement.

2.5 Neat cement grout is mixed in the proportion of not more than six (6) U.S. gallons of clean water per bag (one cu. ft. or 94 lbs.) of cement.

2.6 Additional Notes.* Better flow characteristics can be produced by using cement additives, rather than excessive water which may weaken the grout. "A combination of 5% Bentonite and 95% cement establishes a better seal than pure cement, because Bentonite prevents cement from shrinking when it sets. Bentonite improves the flow of cement grout if it is to be pumped. Fly Ash keeps cement grout stable longer. It prevents the cement and water from separating.

Both Bentonite and Fly Ash are known as "pozzolans" (things which keep finely divided solids in suspension) and may be used almost interchangeably. Unpolished aluminum powder mixed with cement and water causes the mixture to expand.

Use 1/8 oz. unpolished aluminum powder, 4 or 5% (by weight) of Bentonite or Fly Ash, 4¼ to 6 U.S. gallons of water, all per sack (94 lbs. or one cu. ft.) of cement.

Mix the aluminum powder with the dry bentonite first; mix this with the dry cement and then add the water.

Calcium chloride added to cement shortens its setting time. Use 2% by weight. Above 4% will destroy the quality of cement.

"Thoro" Waterplug Cement is designed to set under water and is especially useful for creating impervious bottom plugs in a hole.

"Type 3 Cement" is the name given to "high early" which means high strength with an early set.

Cement does not always set, sometimes a chemical reaction with certain mineral waters prevents it. Bring in fresh clean water to make the grout especially if a "salt" well is to be plugged."

2.7 Cement grouting and Thermoplastic Water Well Casing: When a Portland cement based grout cures, a by-product of the process, the heat of hydration, may subject the thermoplastic water well casing to higher temperatures, which can cause a reduction in strengths of plastic casings. Several steps can be taken to minimize

* From Manual of Water Well Construction Practices — Oregon Drilling Association Inc.

temperature increases during grouting, such as circulation of cool water inside the casing, addition of bentonite to the cement grout etc. When bentonite is added to the grout (say 5% by weight) the curing time is increased. This in turn reduces the rate at which heat is generated during the setting of the cement grout.

3. METHODS OF INSTALLATION OF GROUT

3.1 General Considerations

Positive emplacement of grout by tremie, pumping or pressure is strongly recommended for all wells where the void space is not easily accessible from the ground surface, or where waste disposal wells are being constructed or where the casing has been drawn or where the well has been drilled by jetting or hydraulicing method.

The annular space for positive emplacement methods is to be a minimum of 1½ inches for sand and cement or neat cement grout.

Before grouting the annular space should be flushed to make sure the void is open and ready for grouting.

Where grouting is to exceed 100 feet in total depth, the collapse strength of the casing should first be checked.

The annular space should be filled in one operation and should be completed before the occurrence of the initial set.

Grouting should always be introduced at the BOTTOM of the space to be grouted so as to avoid segregation or bridging.

Grout placement by dump bailer, or by gravity installation without the aid of a tremie or grout pipe should only be used if the interval to be grouted can be seen clearly and is dry and less than 30 feet in total depth below ground surface to ensure adequate visual observation. Bad subsurface water quality zones should be grouted five feet above and below the zone. The annular space surrounding the casing between grouted zones should be filled with sand.

Grout should only extend to within one foot of a pitless adapter or unit casing connection.

Centralizers are required to maintain a minimum annular space where a complete seal is required. Centralizers should be mandatory at the bottom of an irrigation well. In community water supply wells centralizers should be placed in the bottom of the hole and at other critical points.

3.2 Methods of Drilled Well Construction to Provide an Adquate Grout Seal Around the Well Casing

Drilled wells constructed with a surface seal in overburden it is recommended be constructed by first drilling and installing a surface casing of a diameter 4 inches larger than the finished well. In formations where the hole can be kept open the surface casing may not be necessary and a 4 inch oversized open hole can be drilled instead. The annular space between the surface casing or open hole and the permanent inner casing can then be filled with grout. The surface casing can be withdrawn as the grout is placed.

In cases where there is a possibility for contamination of wells drilled into bedrock or drilled wells penetrating clay, hardpan or other relatively stable unconsolidated material, a cement grout seal is recommended which extends from the surface through these formations and in the case of a bedrock well extends 15 feet down into the bedrock.

This cement grout seal in the bedrock well for example, can be achieved by first drilling and installing an oversized casing 4 inches larger in diameter than the finished well, down to the bedrock. The oversized hole is then continued as an "open hole" into the bedrock below the casing to the minimum 15 foot depth. The permanent inner casing is then installed to the bottom of the oversized open bedrock hole. The annular space between the outer casing or open hole and the permanent inner casing is filled with cement grout. The outer casing can be withdrawn as the grout is placed.

3.3 Methods of Grouting the Annular Space Surrounding a Well Casing*

Grout Pipe Outside Casing

If the annular space is of sufficient size to accommodate a grout pipe of such diameter as is necessary to complete operations in the time available, use of such pipe is satisfactory, in fact perhaps the most fool-proof method of grouting. The pipe should extend to the bottom of the annular space initially and should remain submerged in grout during the entire time that grout is being placed. The pipe may be left in place, or it may be gradually removed. In the event of interruption in the grouting operations, the bottom of the pipe should be raised above the grout level and should not be resubmerged until all air and water have been displaced from the grout

* From *AWWA Standard for Deep Wells*
See also *Sanitary Protection of Wells* in Part 1 of these guidelines.

pipe. The grout may be pumped into the pipe or applied continuously by gravity, although this method of placing grout is not advocated for depths in excess of 100 ft. or where the grout level cannot be readily determined by sampling or by displacement calculations. A minimum width of 1½ in. is necessary to accommodate a ¾ in. coupled minimum size grout pipe.

Grout Pipe Inside Casing

A second method of applying grout employs a pipe installed within the casing. The drill hole is plugged below the bottom of the casing, or the grouting operation is conducted when the drill hole has been completed to the depth at which the casing is to terminate. A suitable packer connection, permitting removal of the grout pipe and preventing grout leakage into the interior of the casing pipe, is provided at the bottom of the casing. The casing is suspended slightly above point of bearing, and the grout is forced upward through the annular space by means of pumps or pneumatic pressure arrangements. When the annular space has been filled to the overflow point, the grout pipe is disconnected and pulled out through the casing pipe. The casing may be held in place or lowered to the point of bearing. In deep settings the casing pipe should be kept full of water. After 72 hr. or longer, work on the well may be resumed by drilling out the grout pipe packer connection and plug.

When the well is drilled by the rotary method, the grout may be forced into the annular space in a manner similar to that described above, except that the grout is applied through the hollow drill stem.

Halliburton Method

A third method of grouting is that employed by the Halliburton Oil Well Cementing Co. who hold certain patents thereon. With this method the grout is applied through the casing pipe, being preceded and succeeded by a "spacer" or "piston plug." In brief, the first plug is inserted and the casing capped; a measured amount of grout is applied; the second plug is inserted and the casing capped; a measured volume of water is pumped into the casing until the second plug reaches the end thereof. The first plug drops into the drill hole below the casing, which is suspended sufficiently to provide clearance, while the grout moves upward into the annular space. Neat cement grout is normally used with this method.

APPENDIX No. 4
WELL DEVELOPMENT METHODS*

1. PUMPING OR BAILING METHOD

1.1 Continuous Overpumping

The continuous overpumping method of well development is accomplished by uninterrupted pumping at pumping rates up to 1½ times the design capacity of the well.

1.2 Interrupted Overpumping

The interrupted overpumping method of well development is done with a pump capable of pumping at rates up to 2 times the design capacity. The pumping should be carried out in at least 5 steps. These steps should include pumping rates of ¼, ½, 1, 1½, and 2 times the well design capacity, with no check valve nor foot valve present. Pumping should be conducted in 5 minute cycles, and should continue a minimum of 2 hours or until such time as acceptable standards are attained.

1.3 Surging and Bailing (Utilizing Bailer)

The surging and bailing method of well development is accomplished by utilizing the bailer as a surging device. If fines have been drawn into the well and have settled on the bottom and accumulated to a depth where they block 10 percent or more of the total screen length, the well must be bailed or otherwise cleaned to the bottom before resumption of surging. On completion of development the well should be cleaned to the bottom.

1.4 Surging and Bailing (Utilizing Surge Block)

This development process is carried out by surging and bailing the well. Surging is done with a single or double solid (or valved) surge block. Surging starts at the bottom of the lowest screen in the well and proceeds upwards.

2. MECHANICAL SURGING AND PUMPING METHOD

2.1 Surging and Pumping

In this development process surging is done by either a solid or valve surge block. The pumping is done through the surge block which incorporates a piece of the suction pipe in the fabrication of the block. Pumping is done simultaneously with the surging at rates up to ½ of the design capacity. Fines drawn into the well are pumped out periodically before such accumulation reaches 10 percent of the

* From EPA-570/9-75-001

screen length. Upon completion of the development work the well should be cleaned to the bottom.

3. HYDRAULIC JETTING METHOD

3.1 Hydraulic Jetting

In the hydraulic jetting method well development is accomplished by simultaneous high-velocity, horizontal-jetting and pumping. The outside diameter of the jetting tool should be one inch less in diameter than the screen inside diameter. The minimum exit velocity of the jetting fluid at the jet nozzle should be 150 ft./sec. The tool is rotated at a speed less than one rpm. The jetting tool is positioned at one level for not less than two minutes and then moved to the next level which should be no more than 6 inches vertically from the preceding jetting level. Jetting proceeds from the bottom of the screen to the top. Pumping from the well should be at a rate of 5 to 15 percent more than the rate at which water is introduced through the jetting tool. Water to be used for jetting should contain less than 1 ppm suspended solids. A pump which can deliver a minimum 100 gpm at a minimum 100 psi is generally required.

4. AIR DEVELOPMENT METHOD

4.1 Single Pipe System Open To Atmosphere

In this method, development is done by the utilization of a single pipe air pumping system using the casing or the bore hole itself as the eductor line. The compressors, air lines, hoses, fittings, etc., are of adequate size to pump the well by the air lift principle at 1½ to 2 times the design capacity of the well. Initially the well is pumped with air until it is developed to the point that the well yields clear, sand-free water. Air is then shut off and water allowed to return into the well until a static condition is reached. The valve is then reopened and air is introduced into the well until water is again brought to the surface by the air lift at which time the air valve is closed and the water allowed to drop back down the well and return to a static condition. This process of lifting and dropping of the column of water is repeated until the water in the well becomes turbid at which time the well is then continuously pumped with air until it again yields clear sand-free water. The above operation is repeated until the well no longer produces fine material when it is surged and backwashed as described above.

The bottom of the air line is placed at different levels in order to facilitate development of all intake areas and multiple water producing zones, and the process is repeated until all zones yield water free of turbidity when surged and backwashed.

4.2 Single Pipe System Closed to Atmosphere

For this method a suitable valve is installed on the discharge line leading from the top of the casing, and an air line is secured into a blowing "tee" or "ell" affixed to a valved air connection on the top of the casing. The valve is then closed on the discharge line, and an air hose is attached to the valved fitting and air is introduced into the well, forcing the column of water in the well down. Care must be exercised to prevent air from entering the water-bearing formation. This can be accomplished by the installation of a separate pipe, open to the atmosphere at the top, and installed in the well to a point ten feet above the water-bearing zone. When the water level in the well is forced down to the bottom of this air release pipe, the discharge valve is opened and the water is allowed to rise back to the static level. This procedure can be repeated and/or alternated with the "Single Pipe System Open to the Atmosphere" technique. A pressure gauge and relief valve can be installed at the top of the casing when this system is used.

4.3 Two Pipe System

The development process is carried out by the utilization of an air "introducing" pipe and an air and water eductor line. The compressors, air lines, hoses, fittings, etc., should be of adequate size to pump the well by the air lift method at 1½ to 2 times the design capacity of the well. The well is initially developed as outlined in the above "Single Pipe System Closed to the Atmosphere," with the air line introducing air into the eductor line at a point above the bottom of the eductor line. When the well yields clear sand-free water, the air line can be lowered to a point below the bottom of the eductor line and air introduced until the water between the eductor pipe and the casing is raised to the surface. At this time the air line should be raised back up into the eductor line causing the water to be pumped from the well through the eductor line. The procedure of alternating the relative positions of the air and eductor line is repeated until the water yielded by the well remains clear when the well is surged and backwashed by this technique.

APPENDIX No. 5

COMMUNITY WATER SUPPLY WELLS — GROUNDWATER REPORTS AND WELL TESTS IN SUPPORT OF A CERTIFICATE OF PUBLIC CONVENIENCE AND NECESSITY

1. GENERAL INFORMATION

Well performance and aquifer capabilities must be adequately assessed where a groundwater supply is to be developed for community use. Certain procedures must, therefore, be followed in well testing and the presentation of groundwater information by the applicant to the Comptroller of Water Rights for a Certificate of Public Convenience and Necessity under the Water Utility and Utilities Commission Acts. The intent of these requirements is not to lay down rigid rules but to avoid unnecessary delays or re-tests at the applicant's expense due to inadequate test procedures or report presentations. The Comptroller, with the assistance of the Groundwater Section, Water Management Branch, is prepared on request to review the requirements for any particular case with the applicant or the applicant's engineer prior to the well test.

The applicant is advised to retain the services of a consulting groundwater geologist or a professional engineer whose field of competence lies within the groundwater field. The final groundwater report presented should where possible discuss such points as the geologic setting, aquifer boundaries, recharge conditions, water quality, possibility of pollution, contamination, including salt water and other unpotable water, recommmendations, if any, on a future monitoring program, observation well(s), operation of the well, e.g., overpumping, backwashing, rawhiding, etc. The report is to include a site plan showing locations of the well sites, locations of any unsuccessful test well sites, and any neighbouring wells. The sites are to be shown in relation to existing gazetted roadways, streams and lakes, sanitary land fills, septic field disposal, and the boundaries of any municipalities, improvement districts, etc., in the vicinity. The site plan should show the locations of water sources of other water works within one half mile of the boundaries of the proposed utility, also the location of any wells that may be affected through interference by pumping of the applicants well. A legal description of the proposed well site areas must be provided including where possible registered plan and lot numbers as assigned by the Local Land Registry Office. Approximate elevations should be given on each well assembly, and if possible elevations on important adjacent features such as lake levels, river levels, etc. The report should contain a copy of the well driller's original log for every hole drilled under the program, and also a sketch showing well design specifications for each completed well. Details should be given of the pumping equipment used, and the method of measurement for water well readings and for flow.

At least one sample of the pumped well water must be taken near the end of the pump test and sent for chemical analyses. The analyses should include all major ions, iron and manganese, and tests for other metals if known to be present in the groundwater of the area. A list of recommended parameters is given in Section 3, Appendix 7. Preferably two water samples should be taken, one near the end of the pumping test and one near the beginning of pumping, e.g., almost one hour after start of pumping. The applicant is expected to make his own arrangements with a commercial laboratory for this service. The laboratory's requirements for sample collection and transmission should be adhered to. Samples for bacteriological analyses should also be taken according to the requirements specified by the Ministry of Health. (See Section 4 of Appendix No. 7.)

Pumping tests, recording of data and report preparation should follow standard procedures. For example with field measurements the drawdown and recovery measurements in the pumped well and in the observation wells should be measured in feet to the nearest one hundredth of a foot. The time intervals for both drawdown and recovery readings should be short enough to adequately record any rapid drawdown during start of pumping and any rapid recovery immediately after pump shut down. The time interval after these initial periods can of course then be lengthened between the readings. The pumping rate Q of the water well is to be expressed in U.S. or Imperial gallons per minute or metric equivalents. The pumping rate Q is to remain constant throughout the period of pumping, in the final "constant rate" test. This test will involve continuous pumping at a constant rate for 24 hours or longer (see special conditions). Step drawdown tests or "maximum drawdown" tests can be used initially to determine the Q rate but these tests are not mandatory. Well water must not be allowed to return to the aquifer during the pumping test period. Sufficient discharge pipe must be laid away from the test well to prevent this possibility arising. The reader is referred to the tables on the next page for the type of information to be recorded in pumping and

PUMPING TEST

Depth to water in well from top of casing before test _____ ft.

Time	Time Since Start of Pumping (Minutes)	Depth to Water in Well from Top of Casing (Feet)	Discharge from Well (Gallons/Minute)

For the above table, readings should be taken every minute from 1 to 10 minutes and then every 10 minutes from 10 to 120 minutes (2 hours), then readings every 1½ hours thereafter.

A preferred method for ease in plotting the data, but one that is harder to comply with is as follows:

Readings every 30 seconds from 1 to 5 minutes
Readings every minute from 5 to 10 minutes
Readings every 2 minutes from 10 to 20 minutes
Readings every 5 minutes from 20 to 50 minutes
Readings every 10 minutes from 50 to 100 minutes
Readings every 50 minutes from 100 to 500 minutes
Readings every 100 minutes thereafter

RECOVERY TEST

Time	Time Since Start of Pumping (Minutes)	Time Since Pumping Stopped (Minutes)	Depth to Water in Well from Top of Casing (Feet)

For the above table, readings should be taken every minute from 1 to 10 minutes and then every 10 minutes from 10 to 120 minutes (2 hours), then readings every 1½ hours thereafter. Slow recovery may require that the last readings be spaced as much as 8 to 12 hours apart.

A preferred method for ease in plotting the data, but one that is harder to comply with is as follows:

Readings every 30 seconds from 1 to 5 minutes
Readings every minute from 5 to 10 minutes
Readings every 2 minutes from 10 to 20 minutes
Readings every 5 minutes from 20 to 50 minutes
Readings every 10 minutes from 50 to 100 minutes
Readings every 50 minutes from 100 to 500 minutes
Readings every 100 minutes from 500 to 1,000 minutes
Readings every 500 minutes from 1,000 to 5,000 minutes

recovery tests. A record of any rainfall immediately before, during and after the well test should be reported. Certain conditions may be attached to the certificate with regard to the well source, for example the further collection of data during subsequent well operations and in certain cases a hydrogeological report may be mandatory. These special requirements have to be met where legal problems arise in the development of groundwater supplies such as groundwater withdrawals affecting stream and spring flows which may be under license, where supplies of water to adjacent wells may be affected by pumping or where a producing aquifer is suspected of being limited in extent or capacity.

2. SPECIAL CONDITIONS

A. Boundary Conditions

If recharge or discharge boundaries are detected, then more frequent measurements are also recommended. This can best be done by returning to the time interval set out for the commencement of the test, i.e., "every minute from 1 to 10 minutes," etc.

B. Induced Infiltration

This condition could apply in well sites located adjacent to a surface water body; river, lake, etc.

If equilibrium test conditions are clearly shown, that is, a stable water level in the well in conjunction with a uniform rate of pumping, the test may be terminated prior to the recommended standard 24 hour pumping period.

C. Fractured Bedrock

For wells located in fractured bedrock the pumping rate should be at or in excess of the requirements of the application. The pumping rate must be held constant throughout the testing period which should last for a minimum of 72 hours. In the Gulf Islands and in coastal areas, wells are only to be tested in the middle and late summer and early fall periods. Developers and engineering consultants should coordinate their activities to provide for the testing of wells during the above stipulated periods. Such a procedure would avoid unnecessary delays and will enable a more accurate estimate of well performance to be made.

D. Flowing Artesian Condition

In this special case it is essential to note the artesian pressure head prior to and after a pumping test.

E. Developed Springs and Seepage Sites

In the case of springs and seepage areas developed by excavation into ponds and "holding reservoirs" the following procedures are recommended.

The excavation dimensions must be noted. The reservoir must be (if practical) pumped dry and recovery measurements taken as specified above under general comments. The full recovery should be obtained. Notes regarding entry of water into the excavation should be made where possible.

F. Coastal Aquifers

The need for carrying out the recommended procedures for taking samples of the pumped well water for full chemical analyses is emphasized. It is also strongly recommended that a field test kit be available for testing the chloride content of the pumped water during the pumping test. The purpose of the recommendation is to try to determine possible sea water encroachment. If encroachment is evident the pump test may have to be terminated.

In coastal aquifers the consultant must include data on local tidal fluctuations where these are affecting the apparent drawdown in the test well.

APPENDIX No. 6
WELL DISINFECTION

1. GENERAL

Well disinfection standards must take into account the following:

1. Prior inspection and removal of foreign matter from the well.
2. Scheduling of the disinfection times.
3. Contact time and amounts of disinfection agent to be used.
4. Procedures and equipment required for disinfecting.

All wells should be disinfected by the drilling contractor following completion. Existing Ministry of Health regulations require all new and repaired wells for water works systems to be disinfected before use according to the AWWA standards provided for such disinfection. Also existing wells for water works systems are to be chlorinated as deemed necessary by the Ministry of Health. The guidelines recommended here follow the AWWA recommendations and are given below.

2. CLEANING THE WELL

All oil, grease and scum and any other material which could harbour and protect bacteria from disinfectants should be thoroughly cleared from the well following completion of construction. The casing pipe should be thoroughly swabbed using alkalis if required, to remove oil, grease and joint dope, etc.

3. DISINFECTANTS

Chlorine compounds are considered to be the most suitable disinfectants. The dry

form of chlorine compounds should not have been stored for more than one year and the storage of liquid compounds not more than 60 days. During storage, compounds should not have been exposed to the atmosphere or to direct sunlight.

A minimum concentration of 50 ppm free available chlorine is required in solution when mixed with the total volume of water in the well. See the following table for effective well disinfection.

4. TIME OF DISINFECTION

According to the AWWA standard the time for disinfecting a well is when construction is considered complete and the well is to be tested for yield. Where test pumping equipment is to be utilized, such equipment should be installed prior to or during disinfection and be thoroughly cleaned of foreign material. The well should however, be disinfected before the collection of any samples for determination of bacteriological quality. It is also desirable to disinfect the well after a permanent pump has been installed or when a pump is replaced after repair.

5. DISINFECTION OF NON-FLOWING WELLS

According to the AWWA standard the disinfectant should remain in the well for a period of at least 2 hours.* Following disinfection the well is to be pumped to clear out the disinfecting agent. To protect aquatic life or vegetation, the disposal point for the waste water from the well must be carefully selected.

Method 1: "Where practical, the chlorine solutions of 50 ppm standard concentrations used to disinfect the well should be prepared on the surface in containers having a volume equal to at least twice the volume of water contained in the well. This prepared solution should then be rapidly discharged into the well, care being taken to flush the walls above the water level."

Method 2: A stock chlorine solution of 15,000 ppm (1½% solution) is added to a continuous flow of water into the well to provide the standard 50 ppm standard chlorine concentration.

Method 3: A stock solution sufficient to produce a 50 ppm standard chlorine concentration in the well water is added to the well at different intervals from top to bottom and then agitated to distribute it evenly throughout the well.

Method 4: A perforated pipe container capped at both ends, containing a granular chlorine compound (Perchloron, etc.) is mixed up and down in the well by means of a weighted cable. The amount of compound applied should be such as to provide the standard concentration of 50 ppm available chlorine.

6. DISINFECTION OF FLOWING ARTESIAN WELLS

Flowing wells discharging at the surface generally require no disinfection, however a bacteriological analysis should be made. Should the well prove to be unsafe for use the following disinfection procedures can be used:

Dry chlorine compounds: A capped perforated container filled with a granular chlorine compound is placed at or below the top of the well screen. This process is to be repeated as often as necessary to achieve and maintain the standard 50 ppm

CHLORINE COMPOUND REQUIRED TO TREAT 100 FT. OF WATER-FILLED WELL AT 50 PPM**

Casing Diameter (in)	Volume per 100 Ft. (USg)	70% HTH Perchloron, etc. (Dry Weight)***	25% Chloride of Lime (Dry Weight)***	5.25% Purex Clorox, etc. (US fluid measure)	12% Sodium Hypochlorite (US fluid measure)
2	16.3	1/4 oz.	1/2 oz.	2 oz.	1 oz.
4	65.3	1 oz.	2 oz.	9 oz.	5 oz.
6	146.9	2 oz.	4 oz.	20 oz.	10 oz.
8	261.1	3 oz.	7 oz.	2-1/8 pts.	1-1/8 pts.
10	408.0	4 oz.	11 oz.	3-1/2 pts.	1-3/4 pts.
12	587.5	6 oz.	1 lb.	5 pts.	2-1/2 pts.
16	1044.5	10 oz.	1-3/4 lb.	1 gal.	2 qts.
20	1632.0	1 lb.	3 lb.	1-2/3 gal.	1 gal.
24	2350.1	1-1/2 lb.	4 lb.	2-1/3 gal.	5 qts.

* EPA 570/9-75-001 however, stipulates a 12 hour period..

** EPA recommends a minimum concentration of 100 ppm available chlorine. To obtain this concentration DOUBLE the amounts indicated in the above table.

*** Where a dry chemical is used, it should be mixed with water to form a chlorine solution prior to placing it into the well.

concentrations for a period of not less than one hour.

Controlled flow disinfections: The well cap for this method is to be equipped with a suitable one inch valve. A stock chlorine solution is injected under pressure by means of a drop pipe to the bottom of the well. After injection is complete, air is injected for agitation while simultaneously the valve is opened in the cap permitting the chlorine solutions to be dispersed to the surface. The valve is then closed and the flow stopped for six hours while maintaining the chlorine solution at 50 ppm.

An alternative procedure is to introduce a stock chlorine solution by a drop pipe or hose into the well screen. The rate of application to be such that a standard 50 ppm concentration is achieved and maintained during the application period.

APPENDIX No. 7
WATER SAMPLES AND ANALYSES

1. INTRODUCTION

Water in all wells should be sampled and the necessary field and laboratory tests made so that the groundwater chemical and bacteriological quality of each well and its suitability for its intended use can be determined.

Recommended Water Quality standards have been published by the Provincial Ministry of Health for drinking water and the reader is referred to this publication for further details. The Ministry of Health should be contacted for advice on what additional analyses may be required and on any constituents present in well water which are above the recommended safe limits.

The Environmental Laboratory, Ministry of Environment, provides a water quality check program. This program is a service whereby individuals may obtain analyses of their private water supplies in order to generally determine its suitability for domestic purposes. This service is provided at a subsidized cost, to individuals using or planning to use a water supply. It is not provided to commercial enterprises, consultants, organizations, societies or corporations; nor for the purposes of legal evidence.

The following analyses will be performed on samples submitted under this program:

Total Alkalinity
Calcium
Total Hardness
Total Iron
Magnesium
Fluoride
Nitrate
Nitrite
pH
Dissolved Solids
Specific Conductance
Turbidity
Total Coliforms

It is emphasized that:

1. This program does not replace in whole or in part any other program existing within the government services.
2. The interpretation of the report, with respect to water treatment and health problems, will *not* be made by the laboratory. The Environmental Laboratory will refer such queries to the health districts.
3. The above analyses are the only ones available under this program.

For further information contact the Information Officer, Environmental Laboratory, Ministry of Environment, 3650 Wesbrook Crescent, Vancouver, B.C. V6S 2L2

2. CHEMICAL QUALITY AND COLLECTION PROCEDURES

Water quality field testing kits are useful for early determinations after an aquifer zone has been penetrated. Results based on field kit tests should only be used as a guide and are no substitute for a full laboratory chemical analyses.

Sample collection procedures vary from the use of a bailer — common to the cable tool method to more sophisticated samplers which can take a water sample at a specific depth. Usually samples are collected from the discharge during test pumping or after the production pump is installed. Laboratories have certain procedures that must be adhered to on the collection and submission of samples for chemical analyses including requirements for certain field tests.

A list of recommended parameters for chemical analyses is given below.

3. LIST OF RECOMMENDED PARAMETERS FOR CHEMICAL ANALYSES*

	Units
Phen. Alkalinity	mg/L
Total Alkalinity	mg/L
Sulphate ($SO_4^{=}$)	mg/L
Nitrite and Nitrate ($NO_2^{-} + NO_3^{-}$)	mg/L
Total Kjeldahl Nitrogen (TKN)	mg/L
Total Phosphorous (P)	mg/L
Fluoride (F^{-})	mg/L
Chloride (Cl^{++})	mg/L
Calcium (Ca^{++})	mg/L
Magnesium (Mg^{++})	mg/L
Sodium (Na^{+})	mg/L
Potassium (K^{+})	mg/L
Manganese (Total and dissolved) (Mn)	mg/L
Iron (Total and dissolved) (Fe)	mg/L
Silica (SiO_2)	mg/L
Sp. Conductance	umhos/cm at 25°C
pH	relative units
Total Dissolved Solids (T.D.S.)	mg/L
Total Hardness ($CaCO_3$)	mg/L
Turbidity	(J.T.U.)

* Additional parameters may be required where known or suspected sources of pollution exist.

4. BACTERIOLOGICAL QUALITY AND COLLECTION PROCEDURES

A sample should be taken on all wells to determine bacteriological quality. For new or repaired wells AWWA A100-66 recommends the collection of any sample for determination of bacteriological quality be taken following the disinfection of the well. Chlorine solution must first be removed from the well by pumping, and the chlorine residual reduced to less than 2 ppm before the sample is taken. Special care must be taken in collecting the sample to avoid contacting the inside of the bottle or the cap with the fingers.

The local public health inspector should be requested to obtain a sample for bacteriological analyses when the water is to be used for a public water supply system. In situations where this is not possible, sample bottles and advice on sampling techniques may be obtained through the local health district.

5. RELIABILITY OF SAMPLE RESULTS

The quality of any drinking water supply cannot be determined with confidence from the result of a single sample but rather is possible only by observing the results of several samples over a long period of time. Shallow wells that may be influenced by surface contamination near the well may produce water of varying quality depending on the climatic and physical conditions. Therefore, if a sanitary survey shows a well water supply to be obviously subject to pollution, the water may be condemned irrespective of the test results.

APPENDIX No. 8
PERMANENT WELL, TEST WELL AND TEST HOLE ABANDONMENT

1. INTRODUCTION

Permanent well and test hold abandonment means that the well should be filled in such a manner that vertical movement of water within the well bore, or the annular space surrounding the casing is *effectively and permanently* prevented and the water is permanently confined to the specific zone in which it originally occurred. Unsealed abandoned wells may be a hazard to public health, safety and welfare and to the preservation of the groundater resource. A well needs to be checked first before it is sealed to see there are no obstructions to the sealing operation. Removal of well screens, liner pipes or casings may be necessary in some cases to obtain a permanent seal. Casing opposite zones which cannot be readily removed must be split with a casing ripper to insure subsequent sealing by grout above, and where applicable below, the aquifer zone. Unless the annular space around the outside of the casing was cemented when the well was drilled, the upper portion of the casing should be removed to prevent surface water from entering the water-bearing strata by following down the casing.

2. FLOWING ARTESIAN WELLS

A flowing artesian well particularly if water is escaping around the outside of the casing to surface or even to another

formation needs very special attention. First a permanent cement seal should be placed between the casing and the points from which the water is escaping. However, to do this the flow must first be stopped and the water level lowered in the well. This can be accomplished by:

(a) Pumping the well and drawing down the water level.
(b) Pumping adjacent wells and drawing down the water in the artesian well.
(c) Using high specific gravity fluids to stop the flow.
(d) Where there is a particularly large flow, special measures may have to be taken. These include large stone aggregates (not more than 1/3 the diameter of the hole), steel shavings.

A well packer or a bridge can be used to restrict the flow at the bottom of the confining zone and this enables the appropriate sealing material (usually neat cement or sand and cement grout piped under pressure) to be placed above it.

3. PLACEMENT OF GROUT

Cement grout, sand and cement grout or concrete used as sealing materials in abandonment operations should be placed by the use of grout pipe, tremie, cement bucket or dump bailer in such a way so as to avoid segregation or dilution of the sealing materials. Dumping from the well head should not be permitted.

Where seals are to be placed within casing, liners, filter packs, etc., only neat cement with maximum 5% by weight bentonite clay should be used, and the casing liner, etc., should be first thoroughly perforated or ripped. Elsewhere seals intended to prevent vertical movement of water in the well or bore hole can be cement, sand and cement or concrete. Minimum cement seal length where dimensions permit should be 10 feet.

4. PLACEMENT OF FILL

Above an aquifer the non-producing zones can be filled with sand, sand and gravel, cement and sand or concrete. Non-producing zones above the uppermost aquifer seal should be filled with materials that are *less* permeable than the surrounding formations.

It is recommended that the uppermost 5 feet of the bore hole to land surface be filled with material suitable to the intended land use.

5. SPECIAL CONDITIONS

Mineral exploration holes, dewatering wells, temporary service wells, etc., should also be abandoned according to the above-stated standard for water supply wells.

6. RECORDS

All information relative to the abandonment procedures and methods, the location of the abandoned well, should be recorded on the well record form and copies supplied to the owner and also to the Ministry of Environment.

7. CONCLUSIONS

Because of the complexities involved in some cases of well abandonment, each one should be considered as an individual problem and the design, construction of the well and the hydrogeology must be considered and studied before final selection of materials, methods and procedures can be finalized. It would be wise where there is doubt as to the well construction or the hydrogeology to adopt those materials and procedures which will give the greatest possible chance for a successful and permanent sealing operation.

APPENDIX No. 9
WELL TYPES AND WELL CONSTRUCTION METHODS*

1. TYPES OF WELLS

Water wells can be broadly classified into the following groups:

Dug Wells: Large diameter dug wells are built to obtain water from unconsolidated materials that normally occur in the first 50 feet beneath the surface. In this type of well that may range from 3 to 20 feet in diameter, the walls of the hole are lined in such a way as to prevent cave in of the walls yet still to allow seepage of groundwater into the well base to produce a reservoir of water.

Radial Collector Wells: This type of well usually is constructed of a concrete shaft or caisson from which horizontal intake pipes project radially.

Naturally Developed Screened Wells: This type of well is built to obtain water at various depths from unconsolidated formations which can be stabilized naturally by development following the installation of the casing and screen.

Artificial Filter Pack Wells: This type of well is built to obtain water at various depths from unconsolidated formations that *cannot* be stabilized by the use of a casing/screen combination and natural development only, but in addition require

* From EPA-570/9-75-001
It is impossible to describe in this section all types of wells or even a majority of those in common use. The AWWA Standard for Deep Wells list 11 types of drilled wells and this publication should be consulted for details.

the use of material (sand, gravel, rock) that is coarser than the formation material in the screened interval. This added material acts as an additional screen to prevent the finer aquifer materials from entering the well.

Open Hole - Partially Cased Wells in Consolidated Formations: This type of well is built to obtain water at various depths from consolidated formations (bedrock) either fractured or unfractured. It is not cased or screened in the producing zone, for no formation stabilization or filtering is needed, but it may be cased through the formations above the producing zone if it is unconsolidated or unstable to prevent borehole collapse or to exclude water of undesirable quality.

Open Hole — Partially Cased Wells in Unstable-Consolidated Formations: An additional well type is built to obtain water from unstable potentially caving formations. This type is usually screened through the producing zone and may, under some conditions, require the addition of coarse filter material. The well may not be cased through all the formations above the producing zone, except to exclude water of undesirable quality.

2. WELL CONSTRUCTION METHODS

Well construction methods are many and varied and range from simple digging with hand tools to high speed sophisticated drilling equipment. The most common construction methods are listed below:

Digging Method: In this method the hole is constructed by digging to the desired diameter and depth with hand or power tool. The dug out materials are removed by lifting them from the hole in some type of container. The hole is shored, staved, or cased as the depth is increased. When casing is used, a common practice is to add casing at the surface, allowing it to sink by its own weight as the hole is excavated below the bottom of the casing.

Boring Method: In this method the hole is constructed by the use of a selected diameter hand or power auger which is turned to bore the hole to the desired depth. Cuttings are removed by pulling and emptying the auger or bucket or by the screw action of the auger flite itself.

Driving Method: In this method the hole is constructed by forcing a casing equipped with a drive point into the ground by a series of blows, either manually or machine-delivered, on the top of the casing. Driven wells (or "well points") should be installed only in soft formations that are relatively free of cobbles or boulders. They are feasible only where lifts are shallow and the quantity of water desired is small. Well points can be installed by hand or machine.

Jetting and Hydraulicing Method: The jet drill is basically a combination percussion unit and pressure pump. The pressure pump is mounted on the machine together with pipe and hose connections leading from the pump to the drill pipe, with a return hose from the well casing to a pit or other suitable container. A suction hose returns the water from the pit or container to the pump. The drill pipe consists of a small diameter standard pipe with a bit or chisel attached to the bottom section. Water is forced down through the drill pipe by means of the pressure pump and out through the holes in the bit. This water, being under pressure, carries the cuttings to the surface through the space between the casing and the drill pipe. The lifting and dropping action of the drill pipe chops up the material in the hole and loosens it so that it may be washed to the surface. This method uses a short, fast stroke and is very effective in soft ground, sand and gravel, or other loose unconsolidated formations. This method is best suited for smaller holes of from 2 to 4 inch diameter. A percussion machine is also used for drilling holes by the hydraulicing method. The difference between this and the jetting method is that with the hydraulicing method no pressure pump is needed. The hydraulicing unit utilizes a bit with an opening at the top and a valve seat and ball check valve above it. Water is directed into the hole by gravity in the space between the drill pipe and the casing. The up and down motion of the drill pipe acts as a displacement pump. The ball check valve opens on the down stroke and draws material and fluid into the drill pipe. The valve closes on the up stroke, holding the slurry within the pipe. Eventually the pipe fills up and the mixture of fluid and cuttings are discharged at the surface. Like jetting, the hydraulicing method is fast and efficient in relatively soft formations such as clay and sand.

Cable Tool Method: The cable tool method is used to construct wells by alternately lifting and dropping a set of drilling tools suspended on a wire cable so that with each stroke the drill bit strikes the bottom of the hole. The repeated action of the percussion drill permits bit penetration of the underground formations. The loosened material and drill cuttings are mixed with drilling water by action of the bit and the resulting slurry must be removed from the drill hole by a bailer or sand pump. In drilling a dry hole, water must be added periodically to replace that removed with the drill cuttings. Tools for drilling and bailing are carried on separate lines or cables. Each cable is spooled on a separate drum.

In cable tool or percussion drilling there are basically three major operations: first, the drilling of the hole by chiseling or crushing the rock, clay, or other material by the impact of the drill bit, second, removing the cuttings with a bailer as cuttings accumulate in the hole; and third, driving or forcing the well casing down into the hole as the drilling proceeds. Well casing used in most percussion type drilling operations usually ranges from 4 to 24 inches in diameter. This casing is used to keep the well bore from collapsing and to prevent surface or sub-surface leakage of water or contaminants into the well bore.

Conventional Fluid Rotary Drilling Method: In the conventional mud-rotary method of drilling, drilling is accomplished by rotating a drill pipe and bit by means of a power drive. The drill bit cuts and breaks up the rock material as it penetrates the formation. Drilling fluid is pumped through the rotating drill pipe and holes in the bit. This fluid swirls in the bottom of the hole, picking up material broken by the bit, then flows upward in the well bore, carrying the cuttings to the surface.

The drill pipe and bit move progressively downward, deepening the hole as the operation proceeds. At the land surface, the drilling fluid flows into a settling pit where the cuttings settle to the bottom. From the settling (mud) pit the fluid overflows into a second pit from which it is picked up through the suction hose of the mud pump and recirculated through the drill pipe. In the rotary drilling method the well casing is not introduced into the hole until drilling operations are completed, the walls of the hole being supported by the pressure (weight) of the drilling fluid.

Reverse Circulation Drilling Method: In reverse circulation drilling, instead of circulating the drilling fluid through the drill pipe and up the outside of the pipe, the process is reversed. Fluid is fed down through the space between the wall of the hole and the drill pipe and it is then pumped up, together with the cuttings, through the hollow part of the drill pipe and out a discharge pipe. With the addition of air (applied via a compressor through piping along the drill stem) drilling depths have been increased in one instance, from 450 to 1,000 feet. Of particular importance is the use of a light (nearly clear) drilling fluid which eliminates the need for a viscous and heavy drilling mud used in conventional rotary drilling. The mud sometimes tends to seal-off water-bearing formations. The use of a relatively clear drilling fluid is possible because drilling is rapid; however, a substantial quantity of fluid must be on hand to maintain an open hole.

This method is used for rapid drilling of large diameter holes in soft formations where small boulders are encountered. Boulders up to six inches in diameter can be brought up to the surface through the hollow drill pipe. Such performace is possible because of the extremely high velocity of the fluid as it is drawn up through the drill pipe by the suction pump. In the reverse circulation method, holes 16 inches to 72 inches in diameter have been drilled. The walls of the hole are held in place by the pressure of the fluid against the sides of the hole.

Air Rotary Drilling Method: In the air rotary method of drilling, air serves as the fluid and excavation is accomplished exactly as is done in the conventional rotary method. The bit cuts and breaks up the formation.

Air is forced down through the drilling pipe and out through holes at the bottom of the rotary bit. A stream of water is often introduced into the air system to help cool the drill bit and control dust. The air serves both to cool the drill bit and force cuttings up and out of the hole. The cuttings move up in the annular space between the drill pipe and the wall of the hole, and are collected at the top. Air is used principally in hard clay or rock formations, because once the air pressure is turned off, loose formations tend to cave-in against the drill pipe. This method is not generally recommended for drilling in unconsolidated materials because the quality of the samples are usually poor. Foaming additives are occasionally used to increase the uphole carrying capacity of the return air.

Down-the-Hole (Down-Hole Hammer, Hammer Drilling) Method: The down-the-hole method involves a pneumatically operated bottom-hole drill that efficiently combines the percussion action of cable tool drilling with the turning action of rotary drilling. The pneumatic drill can be used on a standard rotary rig with an air compressor of sufficient capacity. It is used for fast and economical drilling of medium to extremely hard formations. Fast penetration results from the blows transmitted directly to the bit by the air piston. Continuous hole cleaning exposes new formation to the bit and practically no energy is wasted in re-drilling old cuttings. Down-the-hole drilling is generally the fastest method of penetration in hard rock. The bit is turned slowly (5 to 15 rpm) by the same method by which the drill bit in the fluid or air drilling operation is rotated. Foaming additives are occasionally used to increase the up-hole carrying capacity of the return air.

Top Drive Air Rotary with Casing Hammer Method: This is a relatively new

and popular method and it is designed for fast penetration rates. Sand and gravel, boulders and glacial till are drilled and cased simultaneously. Screened wells can be drilled, cased and developed at high speed. The drill pipe is inserted inside the casing and picked up simultaneously with a special adapter when adding drill pipe and casing. After making up the tool joints with the hydraulically powered breakout tongs, the casing is welded and drilling continues. The air operated hammer of one manufacturer develops up to 7,200 foot pounds of driving force at 70 blows per minute with a 24 inch stroke. The hammer can be cleared from over the hole for pulling pipe and for conventional rotary drilling.

APPENDIX No. 10
PITLESS ADAPTER UNITS

1. GENERAL INFORMATION

A well pit can be a source of well contamination from surface or near surface drainage. Pitless well construction sharply reduces the possibility of contaminated water entering the well and system. Pitless adapter units allow termination of the well casing above ground and connection of the discharge pipe underground. Pitless adapters and pitless units are water-tight in design and construction to maintain a sanitary water supply. Water from the well coming up through the drop pipe is connected to the discharge connection by one or more removable seal joints. This permits the drop pipe and pumping equipment in the well to be easily removed from above ground for repair or servicing without disturbing the underground piping. The tank, pump controls, etc., can be placed in a heated location such as a basement offset from the well. Maximum sanitary protection of the offset piping from a pitless adapter requires that the piping be kept under pressure by use of a check valve, etc.

APPENDIX No. 11
THERMOPLASTIC WATER WELL CASING

GENERAL

In preparing the following considerable use was made of material given in two publications:

1. Standard Specifications for Thermoplastic Water Well Casing Pipe and Couplings made in Standard Dimension Ratios (SDR) - ASTM F480-76.
2. Manual on the Selection and Installation of Thermoplastic Water Well Casing 1981, produced by National Water Well Association and the Plastic Pipe Institute.

The reader should refer to these two publications for further details.

Thermoplastic water well casing is made primarily from three thermoplastics:

PVC or polyvinylchloride
ABS or acrylonitrile - butadiene - styrene
SR or styrene rubber

All materials used for wells should meet or exceed the standards set for that material and purpose by the Canadian Society for Testing Materials (CSTM) or the American Society for Testing Materials (ASTM). Thermoplastic water well casing products complying with the ASTM F480 specifications have markings identifying the manufacturer, nominal size, type of material, dimension ratio and manufacturers code.

Which type and diameter of thermoplastic water well casing to use for a particular job will include consideration of the following:

1. Required internal diameter to accommodate the pump.
2. Nature of the formations.
3. Total well depth.
4. Anticipated drawdown.
5. Technique of installation including backfilling technique and method of grouting.
6. Temperature.
7. Technique of well development.

CASING THICKNESS AND DEPTH OF USE

In the tables attached to this Appendix are given the minimum wall thickness and maximum recommended depths of use for three types of thermoplastic water well casing (PVC 12454, ABS 434 and SR 4434), for four standard dimension ratios (SDR 26, 21, 17 and 13.5) listed in the ASTM F480 specifications.

STANDARD DIMENSION RATIO

Standard Dimension Ratios (SDR's) as given in the appendix tables are defined as the ratio of average outside pipe diameter to minimum wall thickness. The advantage of establishing four standard dimension ratios with four groups of minimum wall thickness means that for any given SDR group the collapse pressure is independent of pipe size. For example in the first table in the appendix under SDR 26, PVC 12454, the well casing has the same constant hydraulic collapse strength of 59 psi or 136 ft., (head) of water, over the entire range of pipe diameters.

The SDR system adopted in the appendix tables has definite advantages over the schedule systems i.e., schedule 40, schedule 80, where the SDR ratios of outside diameter to wall thickness may vary from one size to the next and because of this the hydraulic collapse pressures are not constant for all sizes within a schedule and tend to *decrease* in value as the casing diameter increases.

HYDRAULIC COLLAPSE PRESSURE

The hydraulic collapse pressures as given in the appendix tables are a most significant property of thermoplastic water well casing. It

has been determined that a thermoplastic water well casing is most vulnerable to collapse during installation when it has not yet been confined or restrained by the placement of fill material, gravel packing or grout.

Some reasons for differential pressures occurring in the thermoplastic water well casing are:

1. Rapid injection of air during well development, which results in excessive external pressure brought about by the reduction of internal fluid level and density.
2. Rapid removal of the bailer full of drilling mud from the bottom of the well which reduces internal pressure through the suction effect.
3. Extreme drawdown caused by overpumping during some development procedures.

The 1981 NWWA Manual on Thermoplastic Water Well Casing (given above) recommends that a casing be selected so that its resistance to hydrostatic collapse is significantly larger than that required to resist external hydrostatic pressures alone and in the appendix tables attached, a recommended safety factor of approximately two is used in computing the maximum recommended depth of use for three types of thermoplastic water well casing. If we take the same example we used before in the first table in the appendix under SDR 26, PVC 12454, the hydraulic collapse strength is 59 psi or 136 ft., (head) of water. Using a safety factor of approximately 2, the maximum depth of use is 70 feet, i.e., just over half of the collapse strength. In the final analysis the depths to which thermoplastic water well casing can be used is a design judgement. A well casing with adequate packing to support the casing and to prevent casing deformation will allow placement to greater depths as long as the drawdown or head differential before packing is in place will always be within design limits.

TEMPERATURE

ABS thermoplastic water well casing displays the best impact resistance over a wide range of temperatures. Air temperatures lower than about 1.6°C (35°F) will, however, significantly impair the impact resistance of SR thermoplastic. PVC and ABS are impaired at about -26°C (-15°F) and -40°C (-40°F) respectively.

Long term exposure to direct sunlight will cause a gradual loss of impact strength (toughness) that may be significant depending on the plastic, extent of exposure and susceptibility of the casing to mechanical damage. It is therefore recommended that installed well casings projecting above ground be suitably protected. See also Appendix No. 3 Well Grouting, 2.7: Cement Grouting and Thermoplastic Water Well Casing, for effects of higher temperature from heat of hydration.

JOINTS

Thermoplastic water well casing pipe couplings should meet the designated dimensional requirements given in ASTM F480 and the procedures for assembly should conform to that standard.

All thermoplastic water well casing joints must be water tight, and where bell type ends or moulded couplings are used, all joints should be made utilizing solvent cement in accordance with the manufacturers directions. Use of proper techniques for joining casing sections with solvent cement is critical in providing adequate handling strength and in maintaining the integrity of the completed well.

Threaded thermoplastic water well casing pipe couplings should be of the moulded or formed threads type only. The thread lubricant sealant specifically recommended for use with the designated thermoplastic material should be employed.

Thermoplastic casing may also be attached to metallic screens through plastic coupling adapters. Extreme care should be taken while threading the metallic screen into the plastic adapter.

INSTALLATION PROBLEMS

The most common factors which cause problems in the installation of thermoplastic water well casing are:

1. Selection of the incorrect casing for a given installation i.e., the selection of a thin walled casing for a well that must withstand the stress of frequent redevelopment.
2. Joint separations or joint leaks.
3. Placement of gravel pack and/or grout in such a way that substantial, sudden and sometimes unsymmetrical loads are applied to the casing.
4. A well development procedure which produces large pressure differentials on the casing.
5. The rapid shifting of formation material creating point and impact loading on the casing.

MINIMUM WALL THICKNESSES & MAXIMUM RECOMMENDED DEPTH OF USE FOR THREE TYPES OF THERMOPLASTIC WATER WELL CASING (PVC 12454, ABS 434 & SR 4434) FOR TWO STANDARD DIMENSION RATIOS (SDR 26, SDR 21) LISTED IN ASTM F480 SPECIFICATIONS

	SDR 26 Minimum Specifications for Thermoplastic Water Well Casing Up to a Depth of 70 ft.						SDR 21 Minimum Specifications for Thermoplastic Water Well Casing Up to a Depth of 130 ft.					
Nominal Diameter In Inches Of Casing Sizes Covered By These Guidelines	Casing Sizes[5] in Inches, Covered by These Guidelines			Maximum Recommended[1] Depth of Use for Three Types of Thermoplastic Casing in SDR 26			Casing Sizes[5] in Inches, Covered by These Guidelines			Maximum Recommended[1] Depth of Use for Three Types of Thermoplastic Casing in SDR 21		
	Average Outside Diameter	Minimum Inside Diameter[4]	Minimum Wall Thickness	PVC 12454	ABS 434	SR 4434	Average Outside Diameter	Minimum Inside Diameter[4]	Minimum Wall Thickness	PVC 12454	ABS 434	SR 4434
2	—	—	—				2.375	2.05	0.113	130 ft.	115 ft.	100 ft.
2½	—	—	—				2.875	2.51	0.137	130 ft.	115 ft.	100 ft.
3	—	—	—				3.500	3.05	0.167	130 ft.	115 ft.	100 ft.
3½	—	—	—				4.000	3.49	0.190	130 ft.	115 ft.	100 ft.
4	4.500	4.01	0.173	70 ft.	60 ft.	50 ft.	4.500	3.92	0.214	130 ft.	115 ft.	100 ft.
5	5.563	4.95	0.214	70 ft.	60 ft.	50 ft.	5.563	4.85	0.265	130 ft.	115 ft.	100 ft.
6	6.625	5.90	0.255	70 ft.	60 ft.	50 ft.	6.625	5.72	0.316	130 ft.	115 ft.	100 ft.
8	8.625	7.68	0.332	70 ft.	60 ft.	50 ft.	8.625	7.52	0.410	130 ft.	115 ft.	100 ft.
10	10.750	9.58	0.413	70 ft.	60 ft.	50 ft.	10.750	9.37	0.511	130 ft.	115 ft.	100 ft.
12	12.750	11.35	0.490	70 ft.	60 ft.	50 ft.	12.750	11.13	0.606	130 ft.	115 ft.	100 ft.
14	14.000	12.47	0.539	70 ft.	60 ft.	50 ft.	14.000	12.21[3]	0.667[3]	130 ft.	115 ft.	100 ft.
16	16.000	14.25	0.616	70 ft.	60 ft.	50 ft.	16.000	13.95[3]	0.762[3]	130 ft.	115 ft.	100 ft.
Hydraulic Collapse Pressure[2]												
Lbs. per square inch				59	51	47				115	100	92
Ft. (head) of water				136	118	109				265	231	212

[1] NWWA Manual on Thermoplastic Water Well Casing, recommends that a sufficient margin be provided against possible collapse by all normally anticipated external loadings. A casing should be selected so that its resistance to hydrostatic collapse is significantly larger than that required to resist external hydrostatic pressure alone. The above table uses the recommended factor of safety of approximately × 2. Larger factors should be used when it is apparent that greater weight should be given to the other external loadings.

[2] From values calculated in NWWA Manual on Thermoplastic Water Well Casing.

[3] These sizes are under consideration by ASTM for addition to ASTM F480.

[4] From values given in NWWA Manual of Thermoplastic Water Well Casing. These minimum inside diameters assume an average wall thickness of six percent above the specified ASTM minimum.

[5] As given in ASTM F480 and NWWA Manual on Thermoplastic Water Well Casing.

MINIMUM WALL THICKNESSES & MAXIMUM RECOMMENDED DEPTH OF USE FOR THREE TYPES OF THERMOPLASTIC WATER WELL CASING (PVC 12454, ABS 434 & SR 4434) FOR TWO STANDARD DIMENSION RATIOS (SDR 17, SDR 13.5) LISTED IN ASTM F480 SPECIFICATIONS

	SDR 17 Minimum Specifications for Thermoplastic Water Well Casing Up to a Depth of **250 ft.**						SDR 13.5 Minimum Specifications for Thermoplastic Water Well Casing Up to a Depth of **540 ft.**					
Nominal Diameter In Inches Of Casing Sizes Covered By These Guidelines	Casing Sizes[5] in Inches, Covered by These Guidelines			Maximum Recommended[1] Depth of Use for Three Types of Thermoplastic Casing in SDR 17			Casing Sizes[5] in Inches, Covered by These Guidelines			Maximum Recommended[1] Depth of Use for Three Types of Thermoplastic Casing in SDR 13.5		
	Average Outside Diameter	Minimum Inside Diameter[4]	Minimum Wall Thickness	PVC 12454	ABS 434	SR 4434	Average Outside Diameter	Minimum Inside Diameter[4]	Minimum Wall Thickness	PVC 12454	ABS 434	SR 4434
2	2.375	2.01	0.140	250 ft.	225 ft.	200 ft.	2.375	1.94	0.176	540 ft.	475 ft.	430 ft.
2½	2.875	2.44	0.169	250 ft.	225 ft.	200 ft.	2.875	2.35	0.213	540 ft.	475 ft.	430 ft.
3	3.500	2.97	0.206	250 ft.	225 ft.	200 ft.	3.500	2.86	0.259	540 ft.	475 ft.	430 ft.
3½	4.000	3.40	0.235	250 ft.	225 ft.	200 ft.	4.000	3.27	0.296	540 ft.	475 ft.	430 ft.
4	4.500	3.82	0.265	250 ft.	225 ft.	200 ft.	4.500	3.68	0.333	540 ft.	475 ft.	430 ft.
5	5.563	4.73	0.327	250 ft.	225 ft.	200 ft.	5.563	4.55	0.412	540 ft.	475 ft.	430 ft.
6	6.625	5.51	0.390	250 ft.	225 ft.	200 ft.	6.625	5.41	0.491	540 ft.	475 ft.	430 ft.
8	8.625	7.32	0.508	250 ft.	225 ft.	200 ft.	—	—	—			
10	10.750	8.58	0.632	250 ft.	225 ft.	200 ft.	—	—	—			
12	12.750	10.82	0.750	250 ft.	225 ft.	200 ft.	—	—	—			
14	—	—	—				—	—	—			
16	—	—	—				—	—	—			
Hydraulic Collapse Pressure[2]												
Lbs. per square inch				224	196	180				470	412	376
Ft. (head) of water				517	453	416				1086	952	869

[1] NWWA Manual on Thermoplastic Water Well Casing, recommends that a sufficient margin be provided against possible collapse by all normally anticipated external loadings. A casing should be selected so that its resistance to hydrostatic collapse is significantly larger than that required to resist external hydrostatic pressure alone. The above table uses the recommended factor of safety of approximately × 2. Larger factors should be used when it is apparent that greater weight should be given to the other external loadings.

[2] From values calculated in NWWA Manual on Thermoplastic Water Well Casing.

[3] These sizes are under consideration by ASTM for addition to ASTM F480.

[4] From values given in NWWA Manual of Thermoplastic Water Well Casing. These minimum inside diameters assume an average wall thickness of six percent above the specified ASTM minimum.

[5] As given in ASTM F480 and NWWA Manual on Thermoplastic Water Well Casing.

U.S. - IMPERIAL - METRIC (SI) FACTORS

To Convert	To	Multiply By
inches (in)	centimetres (cm)	2.540
feet (ft)	metres (m)	0.3048
miles (mi)	kilometres (km)	1.609
square miles (mi^2)	square kilometres (km^2)	2.590
cubic feet/second (cfs)	litres/second (L/s)	28.32
Imperial gallons (Ig)	litres (L)	4.546
Imperial gallons/day (Igpd)	litres/second (L/s)	5.261×10^{-5}
Imperial gallons/day/ft^2 (Igpd/ft^2)	metres/second (m/s)	5.663×10^{-7}
Imperial gallons/day/ft (Igpd/ft)	square metres/second (m^2/s)	1.726×10^{-7}
Imperial gallons/min (Igpm)	litres/second (L/s)	7.576×10^{-2}
U.S. gallons (USg)	litre (L)	3.785
U.S. gallons/day/ft^2 (USgpd/ft^2)	metres/second (m/s)	4.720×10^{-7}
U.S. gallons/day/ft (USgpd/ft)	square metres/second (m^2/s)	1.437×10^{-7}
U.S. gallons/min (USgpm)	litres/second (L/s)	6.309×10^{-2}
U.S. fluid ounces	litres (L)	2.95727×10^{-2}
Imperial fluid ounces	U.S. fluid ounces	9.6075×10^{-1}
Imperial gallons (Ig)	U.S. gallons (USg)	1.2